NAVFACCO

Naval Facilities Engineering Service Center
Port Hueneme, California

Contract No. 47408-04-C-7526

Final
Revised Groundwater Feasibility Study Report
Installation Restoration Program
Site 70
Naval Weapons Station Seal Beach
Seal Beach, California

August 2005
Volume I of I

Prepared by:

GeoSyntec Consultants
2100 Main Street, Suite 150
Huntington Beach, California 92648-2648
www.GeoSyntec.com
(714) 969-0800

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Signature: ______________________ Date: 8/26/05
Dave Major, Principal

Signature: Walter B. Grinyer Date: 8/26/05
Walter B. Grinyer, P.G. 5893

Foreword

This Revised Groundwater Feasibility Study (RFS) Report for Installation Restoration Program Site 70, Naval Weapons Station, Seal Beach is prepared as an addendum to the existing "*Final Groundwater Feasibility Study Report for Installation Restoration Sites 40 and 70, Naval Weapons Station Seal Beach, Seal Beach, California*" (FS) prepared by Bechtel National Inc., in June 2002, and should be evaluated as such. The RFS is consistent in structure to the existing FS with the same general sections, tables, figures, and appendices. Only report sections, appendices, tables, and figures that have been revised are included in the RFS text; these are labeled with a prefix "R" in the heading to delineate the revised from the original versions. In order to maintain consistency with the original FS, the table and figure numbers within the RFS may not always be sequential and may not start from one. To facilitate the review of the RFS, unchanged figures and tables that are referenced from the existing FS, are included in Attachment A. Where possible, added RFS text, tables, and figures not included within the original FS have been appended to the end of the respective section(s) of the document. The Table of Contents (TOC) in the RFS provides a cross reference for sections, figures, tables, and appendices. The shaded portions of the TOC reflect elements of the FS that have not been altered for the RFS, and are thus incorporated by reference. Unshaded portions of the TOC reflect text, tables, figures, and appendices that have been included within the RFS. The appendices have been incorporated by reference except for the portions that have been edited or added. At this time, Appendix A has not been altered and remains the same as in the existing FS.

EXECUTIVE SUMMARY

This report contains a revised feasibility study (RFS) conducted for Installation Restoration Program (IR) Site 70 at Naval Weapons Station Seal Beach (NAVWPNSTA Seal Beach), Seal Beach, California. This RFS contains a description and evaluation of potential remedial alternatives to mitigate risks to human health from groundwater impacted with volatile organic compounds (VOCs), originating from IR Site 70. The RFS focuses on the evaluation of a bioremediation alternative designed to address IR Site 70 groundwater issues.

The Department of the Navy (DON) is the lead federal agency for environmental cleanup activities at NAVWPNTSA Seal Beach, conducting such work within the context of the IR Program. To implement this program, the DON has elected to follow remedial investigation (RI) and Feasibility Study (FS) protocols prescribed by the United States Environmental Protection Agency (U.S. EPA) for facilities subject to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

This RFS does not identify or recommend a preferred remedial alternative for IR Site 70. Comments made during public and regulatory agency review of this document will be evaluated and considered to select the final remedy. As required by the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) and U.S. EPA guidance (U.S. EPA 1988), these comments will be addressed in the proposed plan and record of decision.

The RFS includes key figures and tables from the existing FS in Attachment A. These figures are provided to assist in the review of this document. The RFS is intended as an addendum to the existing FS and incorporates much of the FS by reference. Throughout the RFS, only sections that have been revised or established the review criteria have been included. All of the section headings have been kept for continuity with the existing FS. The modified RFS sections are indicated by an R in the Table of Contents. Sections, tables, figures, and appendices that have been highlighted in the Table of Contents were not altered from the existing FS (BNI, 2002). To provide continuity with the existing FS, the RFS uses the respective figure numbers from the original document unless they have been modified, in which case the figure number is preceded by an R. Throughout this document, original FS tables, figures, and appendices will be referred to as "FS" and the original identifier, either figure number, table number, or section number. These figures and tables are provided in Attachment A.

The original FS prepared by the Navy's contractor (BNI, 2002) involved screening technologies and associated process options according to effectiveness, implementability, and cost. The retained options were assembled into remedial alternatives. The alternatives were detailed and evaluated against regulatory criteria. Then, the alternatives were compared according to how well they meet regulatory criteria. This RFS includes an evaluation of a new alternative, enhanced bioremediation, against the previous alternatives by using the regulatory criteria.

BACKGROUND

NAVWPNTSA Seal Beach is located in the city of Seal Beach, California. Nearby municipalities include Los Alamitos to the north, Westminster and Huntington Beach to the east, and Long Beach to the west. The Pacific Ocean borders NAVWPNTSA Seal Beach to the south (Figure ES-1).

IR Site 70 consists of multistory office and production buildings, asphalt-paved parking areas, an assortment of aboveground tanks and appurtenant above- and below-ground piping distribution systems and several concrete-lined sumps. During previous investigations, a VOC plume was detected and found to extend approximately 2,400 feet downgradient of the presumed source area. An area proximate to the presumed source area is suspected to contain dense nonaqueous-phase liquid (DNAPL) in dispersed droplet and/or ganglia form (Figure R-ES-3). Dissolved contamination extends to a depth of approximately 195 feet bgs. At 195 feet, a clay layer has been mapped and is presumed to act as a barrier for further downward migration of contamination.

Although chemicals were reported in the groundwater beneath the site, no complete exposure pathways exist between the groundwater and potential ecological receptors. Similarly, the impacted groundwater underlying IR Site 70 does not presently serve as a source of water for beneficial uses designated in the Basin Plan (RWQCB 1995). Accordingly, the impacted groundwater does not pose an immediate threat to human health or the environment.

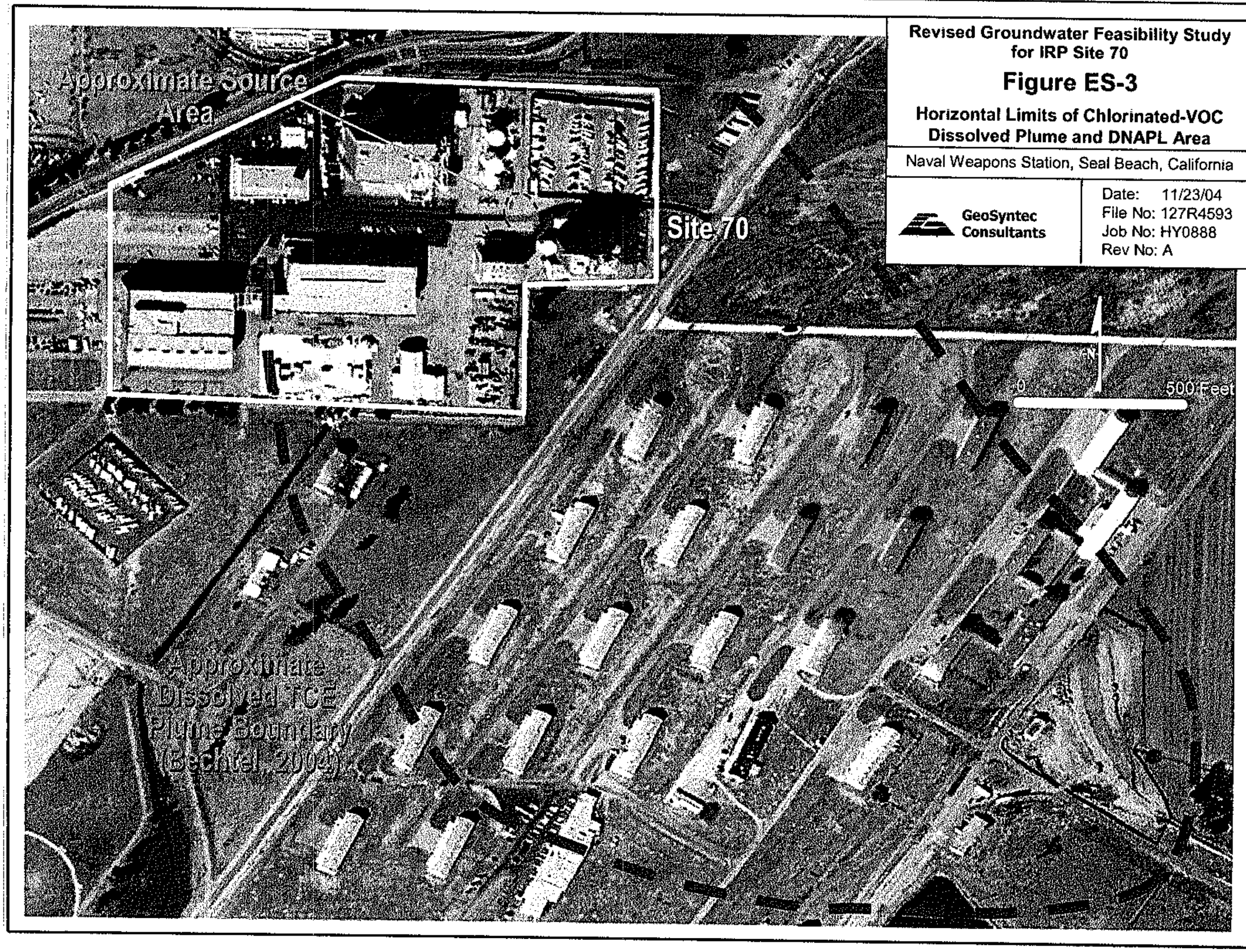
During the extended removal site evaluation (ERSE) (BNI 1999a), a screening human-health risk assessment was performed to estimate the cancer and noncancer risks associated with consumption of the VOC-impacted groundwater at each site. The cumulative human-health risks were estimated to exceed the NCP-defined generally acceptable range. The ERSE therefore recommended that the groundwater be further addressed under the RI/FS to systematically evaluate and select a remedy that would mitigate the risks to human health.

GENERAL RESPONSE/REMEDIAL ACTION OBJECTIVES

General response objectives for the groundwater plumes originating at IR Site 70 are as follows.

- Consistent with U.S. EPA, State Water Resources Control Board, and Regional Water Quality Control Board Santa Ana Region policies and regulations, protect existing beneficial uses of the shallow aquifer underlying NAVWPNTSA Seal Beach to the extent practicable while reducing the potential for VOC migration beyond the current NAVWPNTSA Seal Beach boundaries at concentrations exceeding site cleanup goals

- Protect human health by preventing extraction of VOC-impacted shallow groundwater for domestic use until site cleanup goals are achieved.


Revised Groundwater Feasibility Study for IRP Site 70
Figure ES-3
Horizontal Limits of Chlorinated-VOC Dissolved Plume and DNAPL Area
Naval Weapons Station, Seal Beach, California
GeoSyntec Consultants
Date: 11/23/04
File No: 127R4593
Job No: HY0888
Rev No: A
Approximate Source Area
Site 70
0
500 Feet
N
Approximate Dissolved TCE Plume Boundary (Bechtel, 2004)

General response objectives were used to identify remedial action objectives (RAOs). RAOs are site-specific, qualitative goals that define the purpose of site cleanup. RAOs specify media, constituents of concern (COCs), exposure routes and receptors, and acceptable contaminant levels for protection of potential receptors, based on an analysis of federal and state applicable or relevant and appropriate requirements (ARARs) (i.e., remediation goals).

As a result of developing the RAOs, trichloroethene (TCE), tetrachloroethene (PCE), and their breakdown products were identified as the COCs for IR Site 70 groundwater. Because there are no complete exposure pathways to ecological receptors, the RAOs focus on mitigating potential human exposures to the groundwater. The preliminary RAOs for this FS are defined as the lower of either the U.S. EPA or California maximum contaminant levels (MCLs) for drinking water.

While MCLs have generally been established as preliminary remediation goals for the purposes of this RFS, it should not be construed that the DON accepts these as final remediation goals for IR Site 70. The DON believes establishing final remediation goals is an iterative process, taking into account site-specific factors, such as salt water intrusion, aquifer classification and designated use, and the site- and chemical-specific nature of the groundwater requiring remedial action.

CERCLA EVALUATION CRITERIA

The following nine criteria are stipulated in the NCP at 40 CFR 300.430(e)(9)(iii) for the evaluation of remedial alternatives under CERCLA:

- overall protection of human health and the environment;
- compliance with applicable relevant, and appropriate requirements (ARARs);
- long-term effectiveness and permanence;
- reduction of toxicity, mobility, or volume through treatment;
- short-term effectiveness;
- implementability;
- cost effectiveness;
- regulatory acceptance; and
- community acceptance.

The NCP divides these criteria into three groups: threshold criteria; primary balancing criteria; and modifying criteria. Threshold criteria include overall protection of human health and the environment and compliance with ARARs. Each alternative must meet these criteria to be eligible for selection. The primary balancing criteria include long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. The modifying criteria include state and community acceptance.

RESULTS FOR IR SITE 70

RI Results

Groundwater contamination at IR Site 70 is characterized by higher levels of dissolved VOCs affecting a relatively large area compared to other IR Program sites. The total mass of dissolved contamination at IR Site 70 is estimated to be on the order of 3,200 pounds (BNI, 1999a), and an unknown quantity of DNAPLs is suspected to be present in the vicinity of the presumed contaminant source area. Unless contained or otherwise treated, the suspected DNAPLs could continue to provide a source for dissolved-phase contamination. Groundwater modeling has shown that the plume is moving laterally at depth. Currently, no human or ecological receptors are exposed to VOC-affected groundwater; at this time, there are no complete exposure pathways for contaminants. Shallow groundwater underlying IR Site 70 does not presently serve as a water source for the beneficial uses designated in the Basin Plan (RWQCB 1995).

The groundwater plume at IR Site 70 was analyzed as two separate areas: a suspected DNAPL (source) area and the dissolved-phase plume. Separate remediation alternatives for the DNAPL area and the remaining dissolved plume were developed and then combined to form a sitewide alternative.

Remedy Description

The DON has documented the occurrence of natural attenuation processes at IR Site 70 (BNI, 2002) (as evidenced by trichloroethene daughter products such as cis-1,2-dichloroethene and vinyl chloride). Evidence of natural anaerobic biodegradation has been documented within portions of the plume and, hence, monitored natural attenuation (MNA) was retained for IR Site 70 as a support technology. Although natural attenuation processes were documented, the volume and high levels of contamination and rate of migration of the plume at IR Site 70 necessitate that other measures be considered. MNA was therefore retained as an end-stage technology to reduce contaminant levels in the plume in conjunction with, and following, the application of other technologies. Three other candidate technologies besides MNA were retained for evaluation at IR Site 70.

The original FS evaluated over 17 remedial approaches for Site 70. These included monitored natural attenuation, containment, *in situ* treatment, extraction, ex-situ treatment, disposal, and vapor-phase treatment. *In situ* treatment alternatives included anaerobic biodegradation, air sparging, electrical resistive heating, steam stripping, *in situ* flushing, permeable reaction walls, and chemical oxidation.

Groundwater extraction to hydraulically contain the plume and remove mass, followed by aboveground treatment of groundwater and discharge to surface water was included in the evaluation. Use of vertical wells to extract groundwater and prevent further movement of contaminant plumes is designated as "hydraulic containment," whereas more aggressive approaches employing more wells to remove contaminant mass is termed "pump and treat." These groundwater extraction approaches are considered proven technologies, although many studies have shown it may be difficult to achieve site cleanup goals quickly. One of the limitations of groundwater extraction is that contaminants in groundwater tend to sorb (attach) to adjacent soil particles and, hence, are not extracted quickly. For the dissolved plume, groundwater extraction was evaluated to hydraulically contain the plume (hydraulic containment) and to aggressively remove VOC mass (pump and treat). An aggressive pump-and-treat option was developed and retained for the DNAPL area for hydraulic containment and contaminant mass removal. Advantages and potential limitations associated with these technologies are applicable to IR Site 70. Additionally, because of the suspected presence of DNAPL in the vicinity of the presumed contaminant source area, it was assumed for FS evaluation purposes that an excessively long timeframe could be required for complete remediation using pump and treat.

Bioremediation through anaerobic reductive dechlorination was evaluated to treat both the COCs in the dissolved phase and source areas. The number of wells required to deliver amendments to stimulate the biodegradation of the entire dissolved phase plume is impractical; therefore, bioremediation would involve the segmentation of the dissolved phase plume by creation of bioactive zones that are tangential to the axis of the groundwater flow direction (i.e., biobarriers). The VOCs would be treated as they migrate through these biobarriers that transect the plume. The biobarriers would be created by the addition of a slow release electron donor, which would be immobile relative to groundwater flow, and the injection of requisite halorespiring microorganisms contained in a stable commercially-available culture called KB-1™. The injection of a microbial culture, referred to as bioaugmentation, is required when the key halorespiring strains of the bacterium, *Dehalococcoides ethenogenes* are not present at sites, resulting in partial dechlorination to cis-1,2-dichloroethene (cis-DCE) or vinyl chloride (VC). Bioaugmentation also significantly shortens the time to achieve complete dechlorination of the VOCs to ethene and to meet remedial action objectives (RAO), even if the right strain of *Dehalococcoides ethenogenes* is present, by increasing the population density of this important microorganism. Bioaugmentation has been proven to be a viable approach. The selected electron donor would be emulsified vegetable oil (EVO) that would be metabolized to produce the hydrogen needed by the halorespiring bacteria that breathe chlorinated VOCs.

Impacts to the groundwater flow due to the injection of EVO and KB-1™ are expected to be minimal. Injection of the KB-1™ culture will not impact the permeability of the aquifer, as only ten liters will be amended at each injection point, which is then distributed throughout a pore volume of 3,000 ft^3 to 6,400 ft^3 (i.e., representing less than 0.01% of the pore volume). Typical full-strength bacterial populations have a population count of 10^{12} microbes per liter of groundwater; with each microbe on the order of 0.5 microns in diameter, this represents only 0.04% of the pore volume. The injected emulsified oil is also unlikely to impact soil permeability significantly for 0.5% and 1% oil saturations, with typical reductions in permeability thought to be on the order of at most 5 to 15%, depending on the soil type and pore size. Geotechnical samples from the RI/FS indicate the very well sorted sands in the upper and lower treatment zones.

Porosities for these materials are expected to exceed 30 percent based on literature values. Permeability reductions for this soil type will be at the lower end of the estimated range. The permeability reduction will decrease over time as the oil dissolves.

A similar approach will be applied to the source area where laboratory research and field application have shown that enhancing reductive dechlorination in the source area through addition of electron donor/bioaugmentation results in enhanced dissolution and removal of DNAPL phases. Enhanced bioremediation offers complete destruction of both sorbed and unsorbed components of the VOC plume.

In situ chemical oxidation (ISCO) was evaluated for IR Site 70 specifically for treatment of the suspected DNAPL and high dissolved-phase contamination in the vicinity of the presumed contaminant source area. For IR Site 70, the Geo-Cleanse process, which is proprietary to Geo-Cleanse International, Inc., was evaluated for its ability to inject hydrogen peroxide and trace quantities of metallic salts into the impacted media under pressure. This *in situ* oxidation system offers a potential advantage of permanently destroying a significant quantity of the DNAPL and high dissolved-phase contamination at the IR Site 70 DNAPL area. This process would augment the dispersion and diffusion of the reagent through the soil and/or the affected aquifer. The patented injectors are specially designed to withstand the elevated temperatures and pressures resulting from the Fenton reaction, while achieving effective dispersion of the reagents through the subsurface. However, chemical introduction to the aquifer formation requires administrative acceptance and substantive compliance with existing Waste Discharge Requirements (WDRs). This form of *in situ* chemical oxidation poses certain limitations, as described below.

Because more concentrated reagents would be introduced under pressure, the following additional potential concerns must be addressed: potential for a high rate of uncontrolled vapor release; possibility for soil eruptions and sinkholes; safety hazard presented by violence of reaction; safety concerns regarding handling of reagents; interferences from or reactions with formational materials are possible (increase in total dissolved solids [TDS]); vigorous reactions may occur in the subsurface, and the need for acidification of the aquifer. In addition, some type of bioaugmentation may be necessary to re-establish microorganisms within the ISCO area to re-achieve the MNA process. Bench-scale and pilot-scale testing would be required to implement this technology at the IR Site 70 DNAPL area.

A total of eleven alternatives were developed for this IR Site 70 RFS and the original FS and were initially screened based on effectiveness, cost, and implementability. Alternatives that did not effectively contain and/or treat the dissolved plume were rejected because modeling indicates that the contaminant mass would continue to migrate toward potential water supply points unless action is taken. Alternatives that did not effectively contain and/or treat the suspected DNAPL area were also rejected. Six alternatives were retained for detailed analysis, as listed below. The estimated total cost for each alternative is provided in parentheses.

- ***Alternative 1, no action.*** No further action of any type, evaluated in accordance with the NCP ($0).
- ***Alternative 6, hydraulic containment (dissolved plume) and in situ chemical oxidation (DNAPL area).*** Chemical oxidation of DNAPL area, along with MNA and institutional controls, as necessary, to reduce exposure to contaminated groundwater; hydraulic containment of the leading downgradient edges of the dissolved plume, in association with MNA and institutional controls ($24.2 million).
- ***Alternative 7, hydraulic containment (dissolved plume) and pump and treat (DNAPL area).*** Pump and treat of the DNAPL area in association with MNA and institutional controls; hydraulic containment of the leading downgradient edges of the dissolved plume, in association with MNA and institutional controls ($23.9 million).
- ***Alternative 9, pump and treat (dissolved plume) and in situ treatment (DNAPL area).*** Chemical oxidation of DNAPL area along with MNA and institutional controls; aggressive pump and treat to provide both hydraulic containment and mass removal of the dissolved plume, in association with MNA and institutional controls ($21.6 million).
- ***Alternative 10, pump and treat (dissolved plume) and pump and treat (DNAPL area).*** Pump and treat of the DNAPL area, in association with MNA and institutional controls; aggressive pump and treat of the dissolved plume, in association with MNA and institutional controls ($26.8 million).
- ***Alternative 11, in situ bioremediation using biobarriers for the dissolved phase plume and bioremediation of the DNAPL area through a combination of biostimulation and bioaugmentation.*** Biostimulation/bioaugmentation with a stable halorespiring culture in the DNAPL area combined with the passive application of bioaugmented biobarriers to treat the dissolved plume, with post-treatment polishing using MNA and institutional controls ($18.8 million).

Table R-ES-2 summarizes the revised comparative analysis of the IR Site 70 alternatives by balancing criteria. Alternative 11 (*in situ* biobarriers to treat the dissolved plume and *in situ* bioremediation of the DNAPL area) rates highest overall among the five balancing criteria. Alternative 11 combines an aggressive biostimulation/bioaugmentation *in situ* treatment option for the DNAPL area with a passive *in situ* biobarrier treatment of the dissolved-phase contamination. Recent advances have demonstrated that bioremediation (especially with bioaugmentation using halorespiring cultures) is an aggressive form of treatment within the DNAPL source area. The bioaugmentation approach is compatible with subsequent MNA and should result in lower residual risks in the DNAPL area, following treatment, than other process options evaluated. Groundwater modeling indicates that 99% of the dissolved phase TCE mass would be removed by *in situ* bioremediation treatment within the first six years, with the remaining mass removed by natural attenuation within the dissolved phase plume over the following 9 years (Appendix R-E). Modeling also indicates that containment of TCE mass discharge from the source area will be effectively contained and treated. The amount of biodegraded

DNAPL mass was not simulated due to limitations of the model, and thus the DNAPL mass could not be estimated. Groundwater modeling further indicates RAOs may be achievable within the project life evaluated for this alternative (15 years). An added advantage to the bioremediation approach is the permanent reduction in toxicity, mobility, and volume while minimizing any short or long term risks to workers and overlying structures from the bioremediation approach. The operational reliability of this alternative is rated low, however, due to the innovative nature of this approach and the need to conduct bench- and pilot-scale testing of the biobarrier and DNAPL bioremediation. Alternative 11 is cost effective on the basis that the cost is proportional to its effectiveness, the limited impact to the aquifers, facilities, the environment, and subsequent MNA will be enhanced through the bioremediation approach. This approach had the lowest total cost, but a higher Net Present Value due to up front capital costs.

Alternative 9 (pump and treat [dissolved plume] and *in situ* treatment [DNAPL area]) rates second highest overall among the five balancing criteria. Alternative 9 combines an aggressive chemical oxidation *in situ* treatment option for the DNAPL area with an aggressive pump-and-treat option for mass removal of dissolved-phase contamination. Chemical oxidation is a very aggressive form of treatment and should result in lower residual risks in the DNAPL area, following treatment, than other process options evaluated. Groundwater modeling indicates 1,100 pounds of TCE would be removed by *in situ* treatment within the first year, along with an additional 1,900 pounds of TCE removed by pumping in 10 years. Groundwater modeling further indicates RAOs may be achievable within the project life evaluated for this alternative (50 years). Aggressive pumping in the dissolved plume should make MNA a viable end-stage plume management strategy within 15 years. With regard to the chemical oxidation treatment, potential benefits from reduced duration and permanent reduction in toxicity, mobility, and volume are thought to exceed short-term risks to workers and overlying structures. The operational reliability of this alternative is rated low, however, due to the need to conduct bench- and pilot-scale testing of the chemical oxidation technology. Although Alternative 9 is the second most expensive based on net present worth,, the alternative is cost effective on the basis that the cost is proportional to its effectiveness.

Alternative 6 (hydraulic containment [dissolved plume] and *in situ* treatment [DNAPL area]) rates next highest overall among the balancing criteria. Alternative 6 is differentiated from Alternative 9 by a less-aggressive pumping approach for the dissolved plume. The flow rates for extracted contaminated groundwater resulting from hydraulic containment are about half those for Alternative 9, resulting in a less-expensive remediation approach for the dissolved plume; however, a longer timeframe for pumping is necessary (about 30 years) to reduce contaminant levels sufficiently to revert to MNA. Nevertheless, groundwater modeling indicates RAOs may be achievable within 50 years. As for Alternative 9 above, potential benefits from chemical oxidation of the DNAPL exceed short-term risks, and operational reliability of this alternative is rated low.

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Table R-ES-2
Comparative Analysis of Alternatives by Balancing Criteria, IR Site 70

Alternative*	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost-Effectiveness
Summary of Criteria	Impact of a remedial alternative in the long term, defined as the time after RAOs are met. Consider magnitude of residual risk at the completion of remedial activities; type, degree and adequacy of long-term management from contaminants remaining on-site; long-term reliability of engineering/institutional controls; potential need to replace components and continuing need for repair/maintenance.	CERCLA preference for technologies that permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances. Consider treatment processes used; amount of hazardous material to be treated; degree of expected reduction in toxicity, mobility, or volume; degree to which treatment is irreversible; and type and quantity of treatment residuals	How an alternative affects human health and the environment from planning until RAOs are achieved. Consider short-term risks to community; potential impacts on workers during construction and O&M; potential environmental impacts of the action; and amount of time required before RAOs are achieved (i.e., the duration of the short term).	Technical and administrative feasibility. Consider technical feasibility, including constructability; operational reliability; ability to take alternative remedial actions in the future; ability to monitor effectiveness. Consider ability to obtain governmental approvals. Consider availability of services and materials, including time needed to develop new or innovative technologies under consideration.	Per the NCP, a remedy is cost-effective if its costs are proportional to its effectiveness. Consider capital cost, including both direct and indirect cost, O&M costs, and net present value of capital and O&M costs.
Alternative 1 – No Action	**Low** Under this alternative, there would be no method of assessing long-term effectiveness and permanence.	**Low** No active treatment is performed and no means are available to monitor natural attenuation processes.	**Low** Natural attenuation processes would not be effective in the short term.	**High** Easy to implement.	**Medium** Low cost, but not effective.
Alternative 6 – Hydraulic Containment (dissolved plume) and *In Situ* Treatment (DNAPL area)	**Moderately High** In situ chemical oxidation (ISCO) is a very aggressive form of treatment and should result in lower residual risks in the DNAPL area. Containment of the dissolved phase is a very slow process with mixed results.	**Medium** Modeling indicates 1,100 lb dissolved/sorbed TCE removed within the first year by *in situ* chemical oxidation treatment and 1,800 lb removed by pumping in 30 years. Potential impacts due to pumping of the aquifer (i.e. TDS, salt water intrusion).	**Medium** Groundwater modeling indicates RAOs may be achievable within 50 years.	**Low** Design of chemical oxidation will require bench- and pilot-scale testing. Buffering capacity and TDS of aquifer may interfere with process. Potential for vigorous chemical reactions exists	**Moderately Low** Capital costs are high; however, permanent destruction of VOCs in DNAPL area would provide low cost in proportion to effectiveness.
Alternative 7 – Hydraulic Containment (dissolved plume) and Pump and Treat (DNAPL area)	**Low** Pump and treat has not been shown as a viable treatment alternative for DNAPL. Hydraulic containment of the dissolved phase plume requires an extensive time period.	**Low** Modeling indicates 2,300 lb dissolved/sorbed TCE removed by pumping in 30 years. Pump and treat ineffective on DNAPL. Expect significant impacts to aquifer from pumping.	**Low** Groundwater modeling results indicate RAOs are not achieved within 50 years	**Medium** Demonstrated technology; however, must be carefully designed to minimize disruption to active base operations. Trenching around utilities may be necessary.	**Medium** Low capital costs, but cost in proportion to effectiveness may be questionable.
Alternative 9 – Pump and Treat (dissolved plume) and *In Situ* Treatment (DNAPL area)	**Moderately High** Chemical oxidation is a very aggressive form of treatment and should result in lower residual risks in the DNAPL area. The long term pump and treat of the dissolved phase plume is slow and significantly impacts the aquifer (TDS).	**Moderately High** Modeling indicates 1,100 lb dissolved/sorbed TCE removed within the first year by ISCO treatment and 1,900 lb removed by pumping in 10 years. Expect significant impacts to aquifer from pumping	**Medium** Groundwater modeling indicates RAOs may be achievable within 50 years. Aggressive pumping of the dissolved plume makes MNA in this portion of the plume viable within 15 years. High risks to site workers and facility with ISCO components.	**Low** Design of chemical oxidation will require bench- and pilot-scale testing. Buffering capacity and TDS of aquifer may interfere with process. Potential for vigorous chemical reactions exists. Large volume of pumped groundwater to handle and pipe.	**Moderately High** Capital costs are high; however, permanent destruction of VOCs in DNAPL area would provide low cost in proportion to effectiveness.
Alternative 10 – Pump and Treat (dissolved plume) and Pump and Treat (DNAPL area)	**Medium** This alternative relies on pump and treat and MNA to complete the remediation of residual contamination in the DNAPL area, which may be in the form of contaminants sorbed to the aquifer substrate.	**Medium** Modeling indicates 2,400 lb dissolved/sorbed TCE removed by pumping in 10 years. Expect significant impact to aquifer from salt water intrusion which will impact treatment costs due to fouling.	**Low** Groundwater modeling results indicate RAOs are not achieved within 50 years in all areas	**Medium** Demonstrated technology; however, must be carefully designed to minimize disruption to active maintenance operation. Trenching around utilities may be necessary.	**Low** Low capital costs, but cost in proportion to effectiveness may be questionable

Table R-ES-2 (continued)
Comparative Analysis of Alternatives by Balancing Criteria, IR Site 70

Alternative*	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost-Effectiveness
Alternative 11 – Biobarriers (dissolved plume) and Biostimulation – Bioaugmentation (DNAPL area)	**High** Enhanced bioremediation is a very aggressive form of treatment that has been shown effective in treating both DNAPL and dissolved phase plumes, while allowing subsequent MNA.	**High** Testing under the EPA SITE program has demonstrated DNAPL destruction of up to 98% of the mass within one year using bioaugmentation with KB-1™. Dissolved phase COC destruction has been shown too	**High** Groundwater modeling indicates RAOs may be achievable within 15 years. Enhanced bioremediation is immediately compatible with MNA. Site workers exposed to minimal hazards.	**Medium** Innovative technical application will require some treatability studies Require a large number of injection well points. Possible biofouling and groundwater flow issues may impact the implementation and operation	**High** Lowest total costs, but high capital costs for injection points. Highest net present value costs reflect implementation costs. Permanent destruction of COC's in both DNAPL and dissolved phase plume a plus. Costs for converting to MNA after pump and treat has not been included in the current costs for pump and treat.
Comments	All the alternatives (except No 1 and 11) rely on pumping to remove contamination in the dissolved plume which may impact the aquifer (salt water intrusion). All remedial actions rely on MNA to some extent to achieve RAOs, yet ISCO may not be compatible with MNA. At the completion of MNA, there should be little need for ongoing institutional controls When RAOs are achieved, it is anticipated that no further monitoring/maintenance would be needed.	An estimated 3,300 lb of dissolved/sorbed TCE is present, and unknown quantities of DNAPL may also be present. Chemical oxidation of the DNAPL area rates are higher than pump and treat for the DNAPL area, and aggressive pump and treat rates are higher than hydraulic containment for the dissolved plume under this criterion. Enhanced bioremediation has been shown to destroy both sorbed and dissolved phase COC's	The enhanced bioremediation approach is a low energy but highly effective method to dechlorinate the site that does not pose short term risks to the community, workers, the environment, and the site facilities. None of the alternatives poses short-term risks to the community or differs in terms of environmental impacts. Chemical oxidation poses some short term worker risk but would reduce risks to O&M workers by reducing duration Pump and treat poses significant risk to the aquifer due to salt water intrusion.	Enhanced bioremediation does not require significant impacts to the site or large above ground treatment systems (piping, containment, etc) The alternatives which involve pumping for contaminant mass removal and/or hydraulic containment are demonstrated technology (but extremely long duration) Implementability for alternatives with chemical oxidation and bioremediation are rated lower because of the need to conduct bench- and pilot-scale testing. Chemical oxidation also has the potential for chemical interferences and a complicated (and reactive) reagent delivery system.	Alternatives involving pump and treat of the DNAPL area may need to be operated beyond the assumed 50-year project life, increasing O&M costs. Alternatives implementing significant pumping for containment or treatment may also require significant cost growth for a pretreatment phase if salt water intrusion impacts the carbon treatment efficiency.

Note:
* MNA and institutional controls are included in all alternatives except Alternative 1 (no action)

Acronyms/Abbreviations:
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
DNAPL – dense nonaqueous-phase liquid
IR – Installation Restoration (Program)
lb – pound
MNA – monitored natural attenuation
NCP – National Oil and Hazardous Substances Pollution Contingency Plan
O&M – operation and maintenance
RAO – remedial action objective
TCE – trichloroethene
TDS – total dissolved solids
VOC – volatile organic compound

Alternative 10 (pump and treat [dissolved plume] and pump and treat [DNAPL area]) rates the next highest overall, followed by Alternative 7 (hydraulic containment [dissolved plume] and pump and treat [DNAPL area]), among the balancing criteria. Alternatives 7 and 10 are similar to Alternatives 6 and 9, respectively, in terms of the dissolved plume remediation approach. They are differentiated from the above alternatives by a pump-and-treat approach for the DNAPL area. Groundwater modeling indicates these alternatives would not achieve RAOs within 50 years. Because of the presumed presence of DNAPLs, these alternatives also rate lower in terms of long-term and short-term effectiveness than Alternatives 6 and 9. Alternatives 7 and 10 use a demonstrated technology to contain contamination and accomplish mass removal of dissolved phase contamination and rate medium in implementability. Alternatives 7 and 10 are less expensive than Alternatives 6 and 9, but when costs are weighed against their relative effectiveness, they score only medium in this factor.

Alternative 1 is not a viable alternative for IR Site 70 because it does not afford overall protection of human health and the environment. Contaminant migration would not be monitored or contained, and no restrictions on the use of contaminated groundwater would be in place.

TABLE OF CONTENTS

Section | Page

APPENDICES

FIGURES

Figure

Figure

TABLES

Table

Table

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ACRONYMS/ABBREVIATIONS

ACL	Alamitos Barrier Project
AR	administrative record
ARAR	applicable or relevant and appropriate requirement
BACT	best-available control technology
CAA	Clean-Air Act
Cal-EPA	California Environmental Protection Agency
CAMU	corrective action management unit
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFR	Code of Federal Regulations
CWA	Clean Water Act
DCA	dichloroethane
DCE	dichloroethene
DON	Department of the Navy
DNAPL	dense nonaqueous-phase liquid
DTSC	(Cal-EPA) Department of toxic Substances Control
ERSE	Extended Removal Site Evaluation
FAWQC	federal ambient water quality criteria
FEMA	Federal Emergency Management Agency
FFSRA	Federal Facility Site Remediation Agreement
FS	feasibility study
g	gram
GAC	granular activated carbon
General Permit	General Groundwater Cleanup Permit
gpd	gallons per day
HSC	(California) Health and Safety Code
HWCA	Hazardous Waste Control Act
IR	Installation Restoration
JEG	Jacobs Engineering Group, Inc.
LPC	liquid-phase carbon

MCL	maximum contaminant level
MCLG	maximum contaminant level goal
µg/L	micrograms per liter
mg/L	milligrams per liter
MNA	monitored natural attenuation
MW	monitoring well
NAAQS	National (primary and Secondary) ambient Air Quality Standards
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NPDES	National Pollutant Discharge Elimination System
NTR	National Toxics Rule
NWR	National Wildlife Refuge
PA	Preliminary Assessment
ppm	parts per million
ppmw	parts per million by weight
RCRA	Resource Conservation and Recovery Act
RD/RA	Remedial Design and Remedial Action
ROD	Record of Decision
RWQCB	(California) Regional Water Quality Control Board
SAL	state action level
SCAQMD	South Coast Air Quality Management District
SDWA	Safe Drinking Water Act
SIP	State Implementation Plan
SMCL	secondary maximum contaminant level
STLC	soluble threshold limit concentration
SVE	soil vapor extraction
SWDIV	Southwest Division Naval Facilities Engineering Command
SWRCB	(California) State Water Resources Control Board
T-BACT	best-available control technology for toxics
TBC	to be considered
TCE	trichloroethene
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TSD	treatment, storage, and disposal
USC	United States Code
U.S. EPA	United States Environmental Protection Agency
UST	underground storage tank

VGAC	vapor-phase granular activated carbon
VOC	volatile organic compound
WPNSTA	Naval Weapons Station
WQCP	Water Quality Control Plan
WQO	water quality objective

Section R-1
INTRODUCTION

This report discusses the revised feasibility study (RFS) conducted for Installation Restoration Program (IR) Site 70 at the Naval Weapons Station Seal Beach (NAVWPNSTA Seal Beach), Seal Beach, California (Figures 1-1 and 1-2, Attachment A). GeoSyntec Consultants, Inc. (GCI) prepared this RFS report on behalf of the Department of the Navy (DON), Southwest Division Naval Facilities Engineering Command (SWDIV), under a contract with NAVFACCO, Naval Facilities Engineering Service Center, Port Hueneme, California, Contract No. N47408-04-C-7526.

The original FS proposed Alternative 9, which consists of *in situ* chemical oxidation of the source area and pump-and-treat of the dissolved phase plume. Alterative 9 used monitored natural attenuation (MNA) as the final polishing phase for cleanup. Institutional controls were an additional component of this approach.

This RFS develops and evaluates remedial action alternatives to mitigate human-health risks from volatile organic compounds (VOCs) in groundwater. The DON requested this RFS in response to a Department of Navy directive for optimizing remedial actions. The Navy optimization policy (DON, 2004) requires that all plans to install pump and treat systems on Navy and Marine Corps installations be approved through Naval Facilities Engineering Command headquarters. Based on advancements in bioremediation of dense non-aqueous phase liquids (DNAPL) and dissolved phase volatile organic compounds, the Navy requested that GCI evaluate the use of *in situ* bioremediation alternatives for remediating the site. Although there is no immediate threat to human health or the environment from groundwater at Site 70, the existing FS recommended addressing groundwater at this site because cumulative human-health risk exceeded the generally acceptable range.

The existing FS for IR Site 70 was developed as part of the IR Program. The program identifies, assesses, characterizes, and cleans up or controls pollution from past hazardous waste disposal operations and spills. The program was established to comply with federal requirements regarding cleanup of hazardous waste sites. These federal requirements are outlined in the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA).

The DON, under the Defense Environmental Restoration Program (DERP), follows the United States Environmental Protection Agency (U.S. EPA) remedial investigation (RI) and FS protocols. An RI/FS involves characterizing the nature and extent of risk posed by hazardous waste sites and evaluating options for cleanup. The National Oil and Hazardous Substances Pollution Contingency Plan (NCP) (Title 40 *Code of Federal Regulations* [CFR] 300) provides the RI/FS protocols. The existing FS proposed a remediation approach for Site 70 that would be finalized within the Proposed Plan/Remedial Action Plan (PP/RAP) and Record of Decision (ROD). The DON has decided to re-evaluate the bioremediation technology based on recent developments and pilot study results. This RFS provides the results of that evaluation and proposes a new alternative to finalize under the PP/RAP and ROD.

This RFS is submitted as addenda to the existing FS (BNI, 2002). The RFS follows the same table of contents as the existing FS. Only those sections of the FS that require changes will be modified. Within this RFS document, revised sections, tables, figures, and appendices will be preceded by an "R." References to the original FS will use the section numbers, tables, figure numbers, and appendix letters from the original document (BNI, 2002). The Table of Contents highlights the sections, figures, tables, and appendices that were not altered for this RFS.

R-1.1 PURPOSE AND METHODOLOGY

The DON will use this RFS, in conjunction with other site-specific information, to select an appropriate remedy for groundwater at IR Site 70. The remedial alternatives considered in this RFS include:

- removal of groundwater contamination sources,
- treatment of contaminated groundwater,
- containment of affected groundwater,
- institutional controls, and
- bioremediation within the source area and dissolved phase plume.

A no action alternative is also evaluated, as required by the NCP.

An FS includes the following steps (U.S. EPA 1988).

- Establish remedial action objectives (RAOs).
  - Identify applicable or relevant and appropriate requirements (ARARs).
  - Establish response objectives for all environmental media of concern (e.g., soil, groundwater, surface water, and air), considering contaminant exposure pathways, receptors, and appropriate cleanup levels.
- Identify general response actions, including no action, to meet RAOs for each medium of concern.
- Identify volumes or areas of environmental media for which remedial response actions may be needed.
- Identify remedial technologies and representative process options under each general response action, based on technical considerations.
- Screen remedial technologies and process options based on effectiveness, implementability, and cost.
- Assemble the retained technologies and process options into remedial alternatives representing a range of treatment and containment combinations.
- Screen assembled alternatives considering effectiveness, implementability, and cost.
- Evaluate retained remedial alternatives in detail against nine criteria specified in the NCP:
  - overall protection of human health and the environment

  - compliance with ARARs
  - long-term effectiveness and permanence
  - reduction of toxicity, mobility, or volume through treatment
  - short-term effectiveness
  - implementability
  - cost
  - state acceptance
  - community acceptance
- Perform a comparative evaluation of remedial alternatives.

This RFS identifies a possible remedial approach that will be proposed as the remedial action within the Record of Decision (ROD). The ROD provides the administrative record for public, agency, and Navy concurrence on the remedial approach for groundwater at this site. Comments made during public and regulatory agency review of this document will be evaluated and considered during the remedy selection process. As required by the NCP and U.S. EPA guidance (U.S. EPA 1988), these comments will also be addressed in a proposed plan as well as in the record of decision (ROD). The ROD will document the selected remedial alternative.

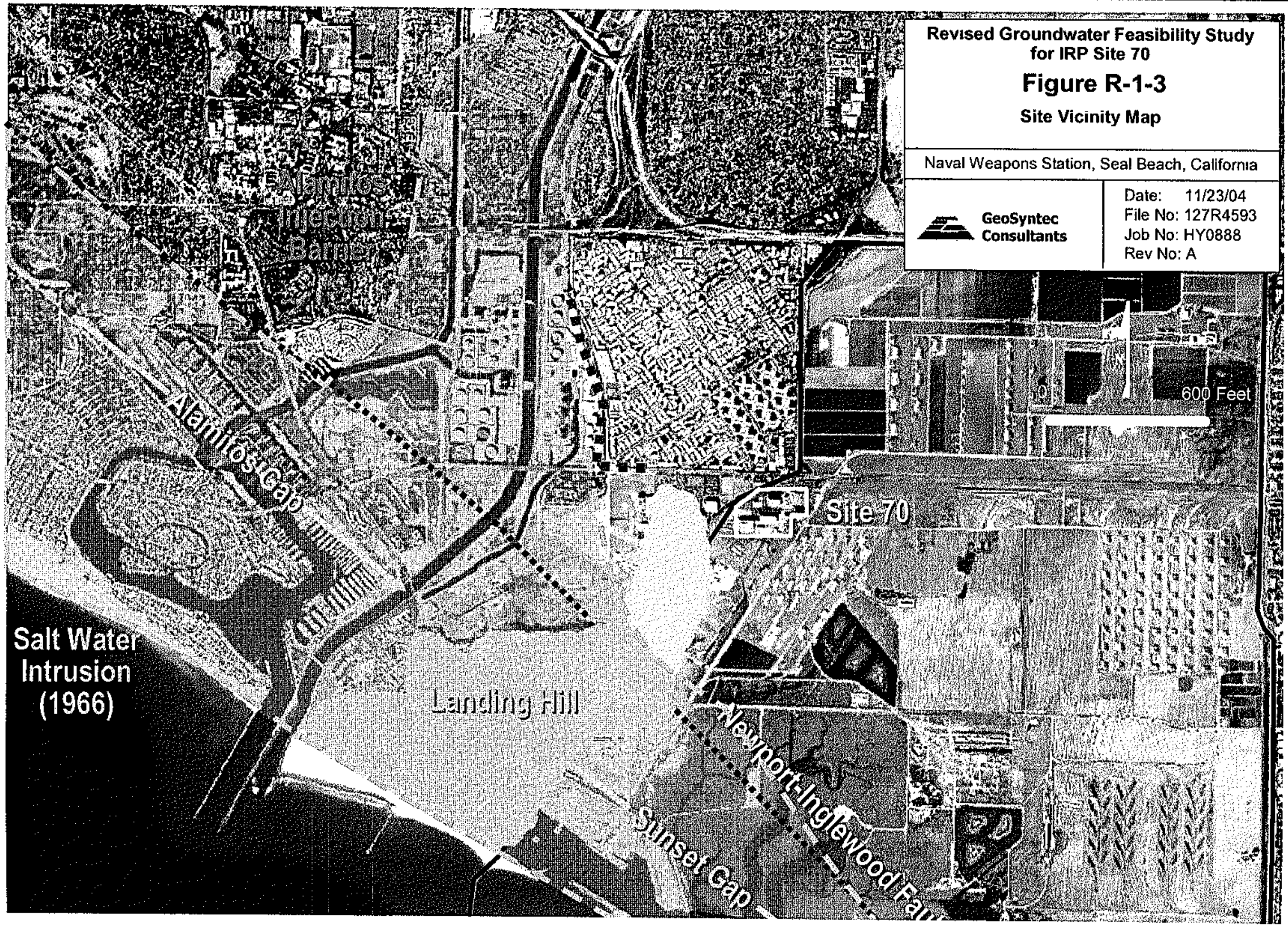
1.2 FACILITY, OPERABLE UNIT, AND IR SITE DESCRIPTIONS

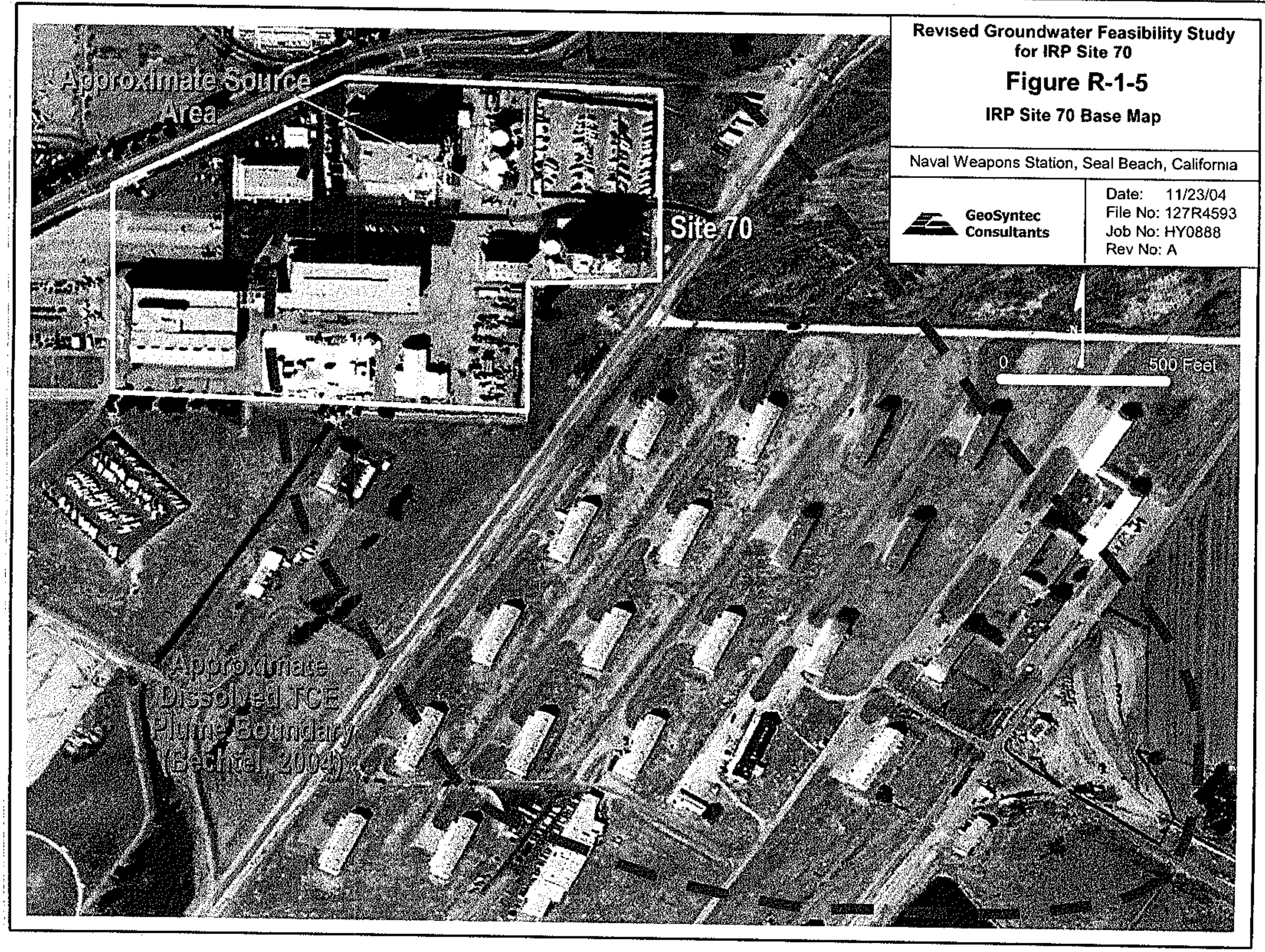
1.2.1 NAVWPNSTA Seal Beach, Seal Beach

1.2.2 Operable Unit Designations

R-1.2.3 Installation Restoration Program Sites

IR Site 70 (Figures R-1-3 and R-1-5), also known as the Research, Testing, and Evaluation (RT&E) area, consists of multistory office and production buildings, asphalt-paved parking areas, an assortment of aboveground tanks and attendant above- and below-ground piping distribution systems, several concrete-lined sumps, and underground storage tanks (USTs). From 1962 to 1973, NASA utilized the area for the design and manufacture of the Saturn II launch vehicle for the Apollo Program. Subsequent to NASA leaving the area, the United States Department of Energy and Garrett Engineering (Allied Signal) conducted pilot test assembly operations for a classified uranium enrichment process in portions of Building 112 (S-03). These tests were conducted from 1980 to 1985 but did not include either the manufacture or enrichment of uranium. Currently, the building is used for storage, communications research, and office space.


Revised Groundwater Feasibility Study
for IRP Site 70
Figure R-1-3
Site Vicinity Map
Naval Weapons Station, Seal Beach, California
GeoSyntec Consultants
Date: 11/23/04
File No: 127R4593
Job No: HY0888
Rev No: A
600 Feet
Site 70
Alamitos Gap
Alamitos Injection Barrier
Salt Water Intrusion (1966)
Landing Hill
Sunset Gap
Newport-Inglewood Fau


Approximate Source Area
Site 70
Approximate Dissolved TCE Plume Boundary (Bechtel, 2004)
0
500 Feet
Revised Groundwater Feasibility Study for IRP Site 70
Figure R-1-5
IRP Site 70 Base Map
Naval Weapons Station, Seal Beach, California
GeoSyntec Consultants
Date: 11/23/04
File No: 127R4593
Job No: HY0888
Rev No: A

The Removal Site Evaluation (RSE) Report (BNI 1996a) for the IR Site 70 area addressed potential waste sources from:

- Bulkhead Fabrication Building 128 (S-02),
- Vertical Assembly and Hydrotest Building 112 (S-03),
- Pneumatic Test, Paint, and Packaging Building 122 (S-04),
- Tool and Maintenance Building 130 (S-05),
- Structural Test Tower (S-06), and
- Water Conditioning Plant (S-07).

Operations at these facilities included the use of dilute acids, VOCs including chlorinated solvents such as trichloroethene (TCE), phenolic compounds, petroleum oils, sodium dichromate containing hexavalent chromium, detergents, metals containing paint wastes, and machine lubricating oil. Discharged wastewater contained high total dissolved solids (TDS), sodium, chloride, and high or low pH.

R-1.3 PREVIOUS INVESTIGATIONS

This FS used information from a number of previous investigations conducted at NAVWPNSTA Seal Beach. The following subsections summarize these investigations, which include:

- general facility investigations:
  - initial assessment study (IAS) (NEESA 1985)
  - RCRA facility assessment (RFA) (A.T. Kearney 1990)
  - preliminary assessment (PA) (NEESA 1990)
- investigations at IR Site 70:
  - PA, IR Site 70 (JEG 1994)
  - Removal Site Evaluation (RSE), IR Site 70 (BNI 1996a)
  - soil and groundwater sampling for Relative Risk Site Evaluation Model (RRSEM), IR Site 70 (BNI 1996b)
- Extended Removal Site Evaluation (ERSE) of IR Sites 40 and 70 (BNI 1999a)
- related groundwater testing at IR Site 70: aquifer testing, including groundwater pumping test and shallow groundwater pilot test (BNI 1999b,c)
- Final Pilot-Test Report for *in situ* Chemical Oxidation at IR Site 70 (BNI, 2004a)
- Final Groundwater Feasibility Study Report for Installation Restoration Sites 40 and 70 (BNI, 2002)

1.3.1 General Facility Investigations

1.3.2 Investigations at IR Site 40

R-1.3.3 Investigations at IR Site 70

In 1993, JEG conducted a PA of IR Site 70 (JEG 1994). Ten Areas of Concern (AOCs) were identified for further evaluation to assess the presence or absence of chemicals of potential concern (COPCs). These ten AOCs were identified based on historical activities, use of chemicals, and the likelihood of a potential threat to human health and the environment. The PA identified major COPCs as hexavalent chromium, TCE, phenolic compounds, trichlorotrifluoroethane (Freon TF), and heavy metals.

BNI conducted an RSE for the RT&E area (BNI 1996a) to address potential waste sources from IR Site 70. The RSE report recommended that process piping systems and facilities be decommissioned and that soil and groundwater in the area be investigated further (BNI 1996a). The report also recommended soil investigations for the presence of hexavalent chromium, vinyl chloride, and heavy metals. Groundwater investigations were recommended to delineate the TCE plume and to determine a potential vadose zone source, as well as the nature and extent of hexavalent chromium, phenolic compounds, and heavy metals.

In 1996, soil and groundwater samples were collected at IR Site 70 to obtain analytical data necessary to populate an RRSEM (BNI 1996b). (Using data collected at NAVWPNSTA Seal Beach and 14 other bases, the RRSEM was used to assist in prioritizing funding for sites in the IR Program.) The samples indicated the presence of VOCs, semivolatile organic compounds, polychlorinated biphenyls, pesticides, and metals.

R-1.3.4 ERSE of IR Sites 40 and 70

In 1998, an ERSE was conducted to supplement data from previous investigations at IR Sites 40 and 70 (BNI 1999a). The ERSE included soil and groundwater sampling. ERSE findings enabled the DON to support a decision of no further action, removal action, or further evaluation. The ERSE:

- better defined the nature and extent of soil and groundwater contamination,
- further refined existing geological and hydrogeological site models,
- evaluated the fate and transport of COPCs from soil to groundwater and within groundwater, and
- evaluated soil and groundwater to assess the potential threat to human health and the environment through screening risk assessments

Although there is no immediate threat to human health or the environment from groundwater at either site, the ERSE report recommended further action to address groundwater at IR Sites 40 and 70 because cumulative human-health risk exceeded the generally acceptable range as defined by the NCP. See Appendix A for details on ERSE findings (BNI 1999a).

R-1.3.5 Groundwater Testing at IR Site 70

Aquifer testing was performed at IR Site 70 in August to September 1998 to further characterize the saturated zone and provide data to support evaluation of remedial alternatives (BNI 1999b). Two extraction wells and five piezometers were installed, and step drawdown tests were performed in the extraction wells. A constant discharge rate pumping test was also performed in the shallow groundwater well. Groundwater samples were collected during pumping tests (Appendix A).

From November 1998 to February 1999, BNI conducted a shallow groundwater pilot test at IR Site 70 (BNI 1999c). The pilot test consisted of pumping 2.5 gallons per minute (gpm) from a well near the contamination source for 3 months. The saturated zone was characterized by determining the contaminant concentration distribution before and after the pilot test and defining the effective pumping radius of influence and groundwater parameters (Appendix A).

1.4 REGULATORY STATUS

1.5 PHYSICAL SETTING AND CLIMATE

R-1.6 REGIONAL GEOLOGY/HYDROLOGY/HYDROGEOLOGY

Regional geology and hydrogeology is summarized in the original FS and Appendix A. Appendix A in the original FS provides more details.

1.6.1 Regional Geology

1.6.2 Water Supply

1.6.3 Surface-Water Hydrology

1.6.4 Hydrogeology

R-1.7 SITE CONDITIONS – IR SITE 70

This section presents general information on site conditions at IR Site 70, including geology/hydrology, groundwater chemistry, nature and extent of contamination, and contaminant fate and transport. See Appendix A for more details.

1.7.1 IR Site 40

1.7.1.1 GEOLOGY, HYDROLOGY, AND HYDROGEOLOGY

1.7.1.2 GENERAL GROUNDWATER CHEMISTRY

1.7.1.3 NATURE AND EXTENT OF CONTAMINATION

1.7.1.4 CONTAMINANT FATE AND TRANSPORT

R-1.7.2 IR Site 70

The following subsections discuss site conditions at IR Site 70.

R-1.7.2.1 GEOLOGY, HYDROLOGY, AND HYDROGEOLOGY

IR Site 70 has a groundwater contaminant plume to approximately 190 feet bgs. The lateral and vertical extent of the plume has been delineated. The groundwater gradient varies in the flow direction, which is normally southeast. This direction reverses itself seasonally, and movement of the plume in groundwater is relatively slow. The sediments span a wide range of lithologies and grain sizes (see cross sections in Appendix A).

Observed Geologic Units

The geologic units observed at IR Site 70 are as follows (BNI 1999a).

- Surficial soils – Fill materials, including sandy clay and predominantly fine-grained clayey sand to silty sand up to about 7 feet thick. Off-site to the southeast, surficial soils consist of approximately 2 to 17 feet of native sand, silty sand, clayey sand, and sandy clay, occasionally including thin lenses of silt, silty clay, and clay.
- Shallow clay unit – A typically 15- to 25-foot-thick interval consisting of clay to silty clay, which grades locally to sandy clay, clayey silt, or silt. Shallow groundwater has been typically encountered within the coarser-grained surficial materials in the underlying clay or just beneath the clay, depending on the location and time since last rainfall.
- Interbedded unit – Interbedded clays, sandy clays, clayey sands, silts, and silty sands. This unit is typically thickest to the northwest, where it extends to approximately 54 feet, thinning southeastward to a 3- to 10-foot-thick sandy silt to silty sand interval.
- First sand unit – Fine- to medium-grained sand, with coarse-grained sand to gravel, grading to silty sand in some areas. The unit also seems to contain several discontinuous silt, silty clay, or clay interbeds. The total unit thickness typically varies from approximately 40 to 80 feet, thickening to the southeast. The top of the unit varies from 22 to 54 feet bgs (and is deeper to the north); its base occurs at 87 to 115 feet bgs.
- Shell horizon – Sand and shells. The sand is typically fine- to coarse-grained, although is locally fine-grained or fine- to medium-grained. Depth to the top of the shell unit ranges from 87 to 115 feet bgs. The unit typically extends to 96 to 130 feet bgs.
- Second sand unit – The shell horizon is underlain by another unit consisting mainly of sand. The sand is typically fine- to coarse-grained, although it locally contains gravel, which grades silty sand in some areas. The unit also contains apparently discontinuous silt, silty clay, or clay interbeds in some areas. The

top of the unit varies from 96 to 130 feet bgs; its base occurs at 164 to 176 feet bgs. The total unit thickness varies from 34 to 78 feet but pinches out to the southeast.

- Deep clay unit – An apparently continuous unit consisting mainly of clay to silty clay is encountered at depths between 164 to 176 feet bgs. The unit grades to clayey silt, silt, sandy silt, or sandy clay in some areas. It is 3 to 20 feet thick, extending to between 175 and 188 feet bgs. The unit is underlain by up to 6 feet of silty sand and sand to the maximum depth of the ERSE borings (191 feet bgs).

Conceptual Model

The revised site physical conceptual model generally represents the location and assumed lateral continuity of the hydrostratigraphic units beneath the IR Site 70 vicinity (Figure R-1-18). The model incorporates the uppermost approximately 190 feet bgs, which includes Recent Age sediments and Late Pleistocene sediments of the Lakewood Formation. The model was developed using data from the RI (BNI, 2002, BNI, 1999a).

During the pumping tests (BNI, 1999b,c), additional data were incorporated into development of a conceptual model for the IR Site 70 source area. GCI developed a three dimensional visualization of the site conceptual model, which is presented in Figure R-1-19. The additional investigation confirmed the presence of a relatively impermeable shallow clay layer from approximately 2 to 20 feet bgs in the vicinity of the source area.

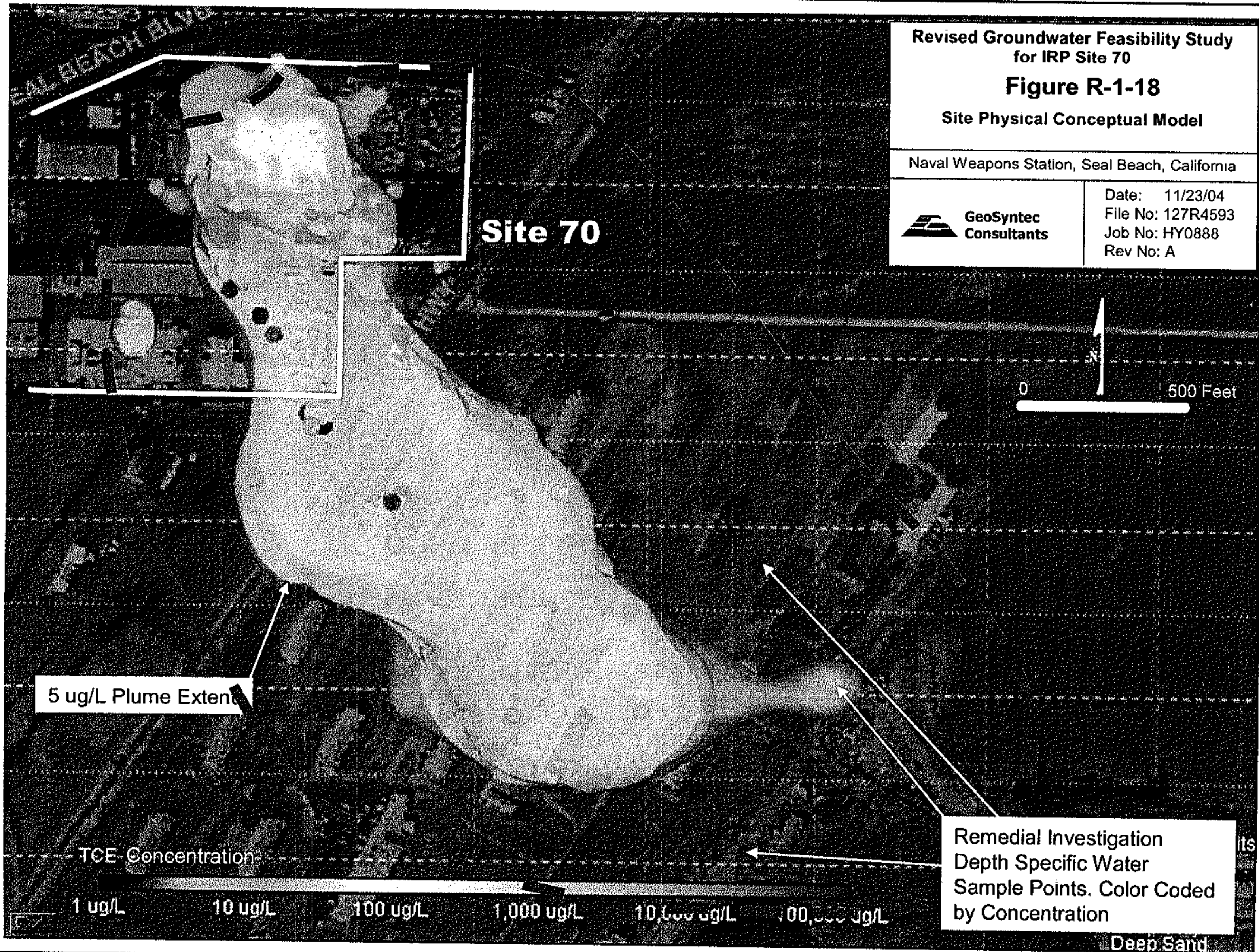
Aquifer Test Results

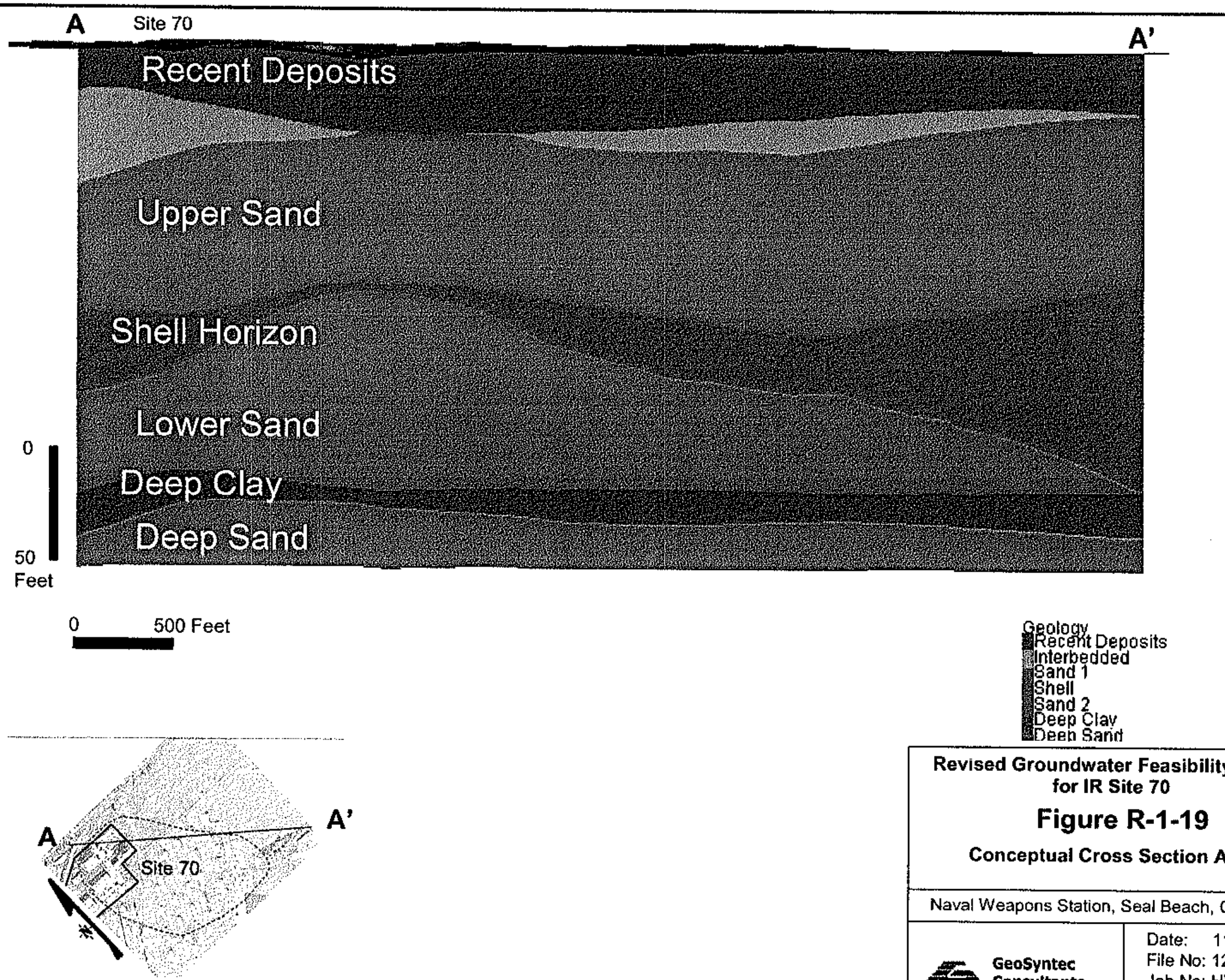
The hydraulic conductivities of screened intervals in selected ERSE groundwater monitoring wells were determined based on aquifer (slug) tests (See Appendix A for aquifer test results [BNI, 2002]). Hydraulic conductivity values are summarized below.

- shallow (20 to 30 feet bgs), 0.85 to 4.55 feet/day;
- intermediate (50 to 60 feet bgs), 3.25 to 7.89 feet/day;
- deeper zone (95 to 110 feet bgs), 14.15 to 95.93 feet/day; and
- deepest zone (160 to 170 feet bgs), 11.55 to 299.59 feet/day.

These results show that hydraulic conductivity values for deeper zone wells are typically at least an order of magnitude higher than for shallow and intermediate interval wells.

Additional aquifer testing was performed for pump tests conducted at the IR Site 70 source area and vicinity (Section 1.3.3, BNI, 1999b). Step drawdown and constant discharge pumping tests were performed on a shallow well in the vicinity of the IR Site 70 source area screened within the interbedded unit (Appendix A [BNI, 2002]). The transmissivity of the interbedded unit for the pilot test at 2.5 gpm was approximately 0.1 square foot per minute, and the storage coefficient was approximately 0.006. Based on a saturated thickness of 15 feet for the tested interval, the hydraulic conductivity was approximately 0.007 foot per minute, or 10 feet per day. The radius of influence for the pumping test was approximately 240 feet.


Revised Groundwater Feasibility Study for IRP Site 70
Figure R-1-18
Site Physical Conceptual Model
Naval Weapons Station, Seal Beach, California
GeoSyntec Consultants
Date: 11/23/04
File No: 127R4593
Job No: HY0888
Rev No: A
Site 70
N
0
500 Feet
5 ug/L Plume Extent
Remedial Investigation Depth Specific Water Sample Points. Color Coded by Concentration
TCE Concentration
1 ug/L
10 ug/L
100 ug/L
1,000 ug/L
Deep Sand



Revised Groundwater Feasibility Study for IR Site 70

Figure R-1-19

Conceptual Cross Section A-A'

Naval Weapons Station, Seal Beach, California

GeoSyntec Consultants

Date: 11/23/04
File No: 127R4593
Job No: HY0888
Rev No: A

The 90-day shallow groundwater pilot pumping test (BNI 1999c) included determining VOC concentrations before, during, and after the pilot test and confirmation of the transmissivity, storage coefficient, and pumping radius of influence near the shallow pumped well EW-70-01 (Appendix A). The transmissivity of the interbedded unit for the pilot test at 2.5 gpm was determined to be approximately 0.1 square feet per minute, which confirms the previous pumping test result. The storage coefficient is approximately 0.004, which is similar to the value of 0.006 determined from the pumping test data and the value of 0.003 determined from the previous flow model calibration. Based on a saturated thickness of 15 feet for the tested interval, the hydraulic conductivity was approximately 0.007 feet per minute, or 10 feet per day. The radius of influence for the pilot test was approximately 230 feet.

Groundwater Flow

Groundwater flow is locally influenced by tides (BNI 1999a). Most shallow and intermediate wells fluctuate less than 0.1 feet as a result of tidal influences. Water levels in deeper wells have fluctuated from 0.15 to 0.20 feet.

Seasonal influences appear to change the groundwater surface gradient direction in the shallow zone and intermediate zones. Groundwater flow within the deeper zones is generally toward the southeast. Seasonal influences for the deeper zones are under evaluation.

Based on consistently downward head differences of typically 1 to 3 feet between shallow zone and intermediate zone wells, the vertical gradient is estimated to be typically 0.03 to 0.1 ft/ft. A smaller downward gradient of 0.001 to 0.005 ft/ft is estimated between the deeper zone wells screened at 95 to 105 feet bgs and wells screened at 160 to 170 feet bgs, where head differences are less than 0.1 to 0.3 feet. Additional discussions of vertical head differences are included in Appendix E (Sections E2.2.1, E2.4.3, and E2.5.2).

R-1.7.2.2 GENERAL GROUNDWATER CHEMISTRY

General groundwater chemistry data (BNI 1999a) indicate the following:

- Groundwater quality at IR Site 70 ranges from fresh to saline, depending on location and depth interval, based on TDS.
- Chloride is the major anion present in groundwater located beneath IR Site 70.
- Major cations include calcium, magnesium, sodium, and potassium.
- Dissolved gases (methane, ethane, and ethene) are locally present.
- Dissolved iron and manganese are locally present.
- Total organic carbon is locally present; the highest concentrations are reported in center-of-plume wells and located within the defined boundary of the VOC plume.

- Specific conductance and salinity values indicate that shallow groundwater underlying IR Site 70 ranges from fresh to brackish to slightly saline.
- pH values suggest that the groundwater is slightly basic.
- Based on concentrations of dissolved oxygen and ORP values, the groundwater environment beneath the area is moderately reduced to reduced. ORP values were positive within the shallow-water interval and negative in the intermediate and deeper water intervals.
- Ferrous iron is locally present.

R-1.7.2.3 NATURE AND EXTENT OF CONTAMINATION

BNI further investigated soil and groundwater contamination at IR Site 70 during the ERSE (BNI 1999a). Soil sampling and analyses focused on:

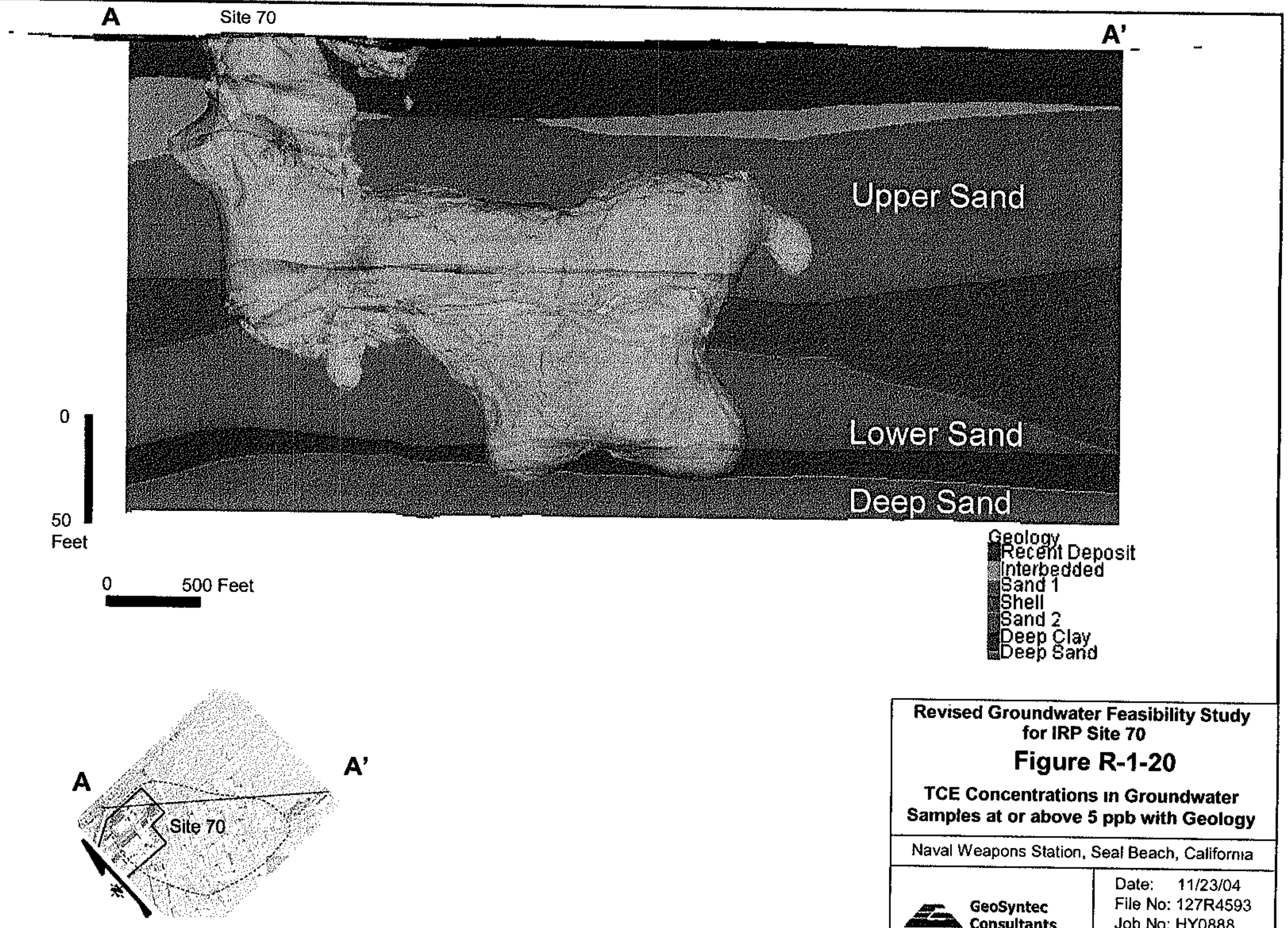
- determining the presence of VOCs, SVOCs, hexavalent chromium (Cr^{+6}), heavy metals, pesticides and polychlorinated biphenyls (PCBs) in the vadose zone soils and (if present) delineating the vertical and lateral extent and potential for impact to groundwater; and
- delineating the vertical and lateral extent of chlorinated solvents (TCE, PCE, and degradation products) within vadose zone soils and assessing the potential to serve as an ongoing source of VOC contamination to groundwater.

AOCs included:

- Former Stormwater Drainage Channel (AOC 2),
- Saltwater Discharge Point (AOC 3),
- Perimeter Drainage Channel (AOC 4), and
- Area North of Building 112 (AOC 11).

The ERSE recommended no further action for three of the AOCs (AOC 2, AOC 3, and AOC 11) and further evaluation for AOC 4. However, in each case, the fate and transport evaluations demonstrated that the potential for COPCs in soil to leach to the groundwater and be transported in the groundwater is low to negligible (BNI 1999a).

GCI has evaluated the data sets for IR Site 70. From this evaluation, the data were entered into a three-dimensional visualization software package to provide graphic visualizations of the TCE plume. Figure R-1-20 provides a 3-dimensional representation of the greater than 5 $\mu g/L$ (5 ppb) TCE plume. This view of the data shows a vertical trend beneath the source area and a horizontal trend along the shell horizon.



Revised Groundwater Feasibility Study for IRP Site 70

Figure R-1-20

TCE Concentrations in Groundwater Samples at or above 5 ppb with Geology

Naval Weapons Station, Seal Beach, California

GeoSyntec Consultants

Date: 11/23/04
File No: 127R4593
Job No: HY0888
Rev No: A

Figure R-1-21 provides a view of the 50 μg/L (50 ppb) isochron (equal concentration) surface. This view accents the vertical and horizontal components of the plume. This plume limit captures over 80 percent of the dissolved phase mass. Although the plume is approximately 2,400 ft long by 2,000 ft wide, Figure R-1-21 shows that the plume staircases through the site lithology to its deepest point at the southeastern edge of the plume. Figure R-1-22 provides a 3-D visualization of TCE above 10,000 μg/L, the inferred DNAPL areas. From this visualization, we can better define the remedial approach.

More information regarding the nature of contamination at the IR Site 70 source area is presented in the shallow groundwater pilot pumping test report (BNI 1999c). See Appendix A for more details on the nature and extent of contamination at IR Site 70.

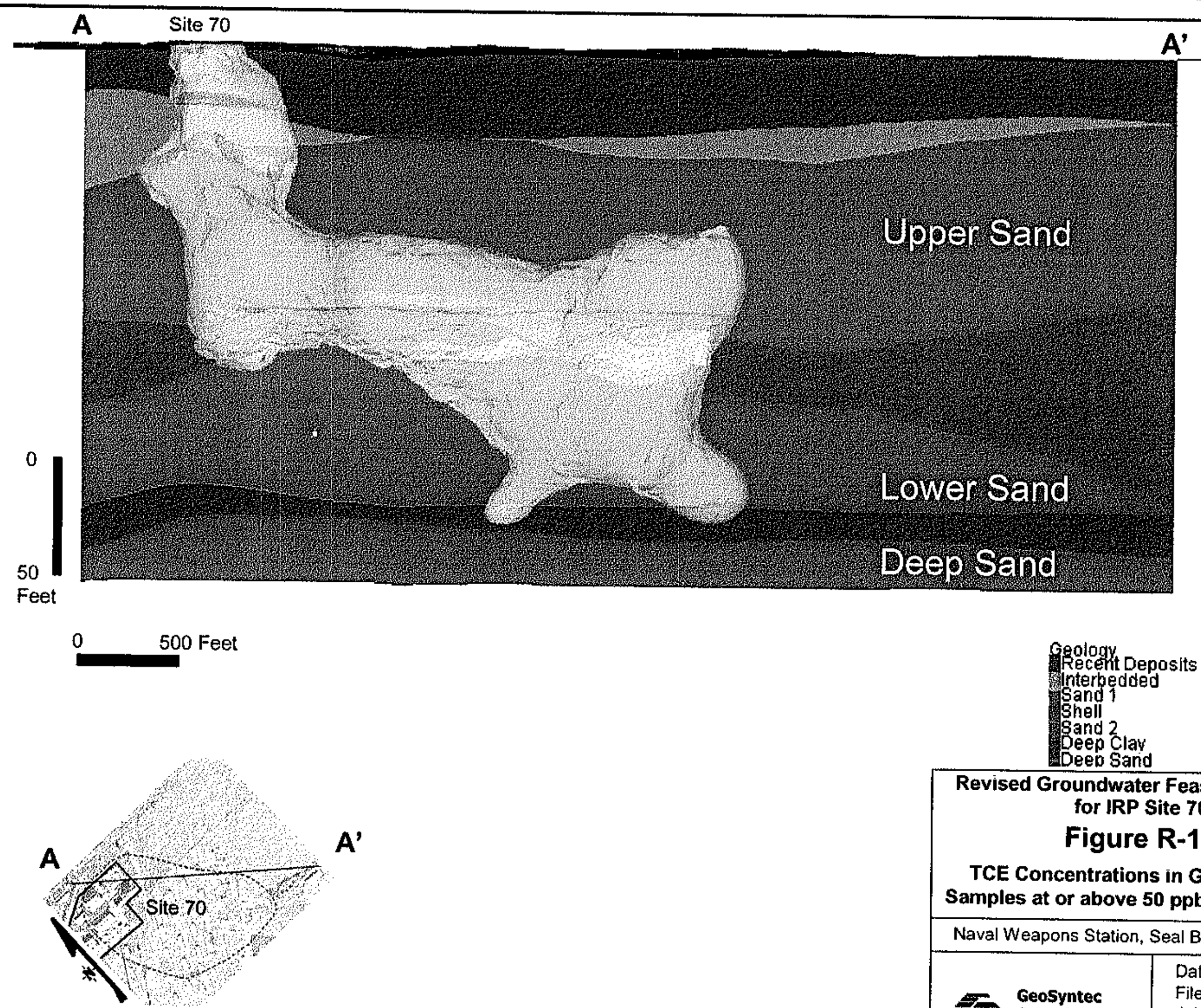
1.7.2.4 CONTAMINANT FATE AND TRANSPORT

1.8 SUMMARY OF SCREENING RISK ASSESSMENT

R-1.9 REPORT ORGANIZATION

The RFS report incorporates the existing FS report sections, appendices, tables, and figures by reference unless the revised section, appendices, tables, and figures are included in the RFS. The existing FS report included seven main sections and five appendices; the RFS includes the revised text portions for the seven sections and revised Appendices R-B, R-C, R-D, and R-E. Attachment A provides tables and figures from the original FS for ease of reference. Modifications to the existing tables and figures have been made to evaluate the enhanced bioremediation alternative. The FS includes the following sections and appendices:

- Section 1 provides an overview of the CERCLA FS process and summarizes significant findings from the ERSE completed at IR Sites 40 and 70 and pumping tests at IR Site 70.
- Section 2 outlines the RAOs.
- Section 3 identifies and screens various remedial technologies and process options for contaminated groundwater.
- Section 4 develops technologies and process options into remedial alternatives and screens the alternatives as appropriate.
- Section 5 provides a detailed analysis of remedial alternatives using NCP criteria.
- Section 6 compares the remedial alternatives based on NCP criteria.
- Section 7 provides references cited.
- Appendix A summarizes previous investigations, most notably the ERSE (BNI 1999a) and the pumping tests at IR Site 70 (BNI, 1999b,c).



Revised Groundwater Feasibility Study for IRP Site 70

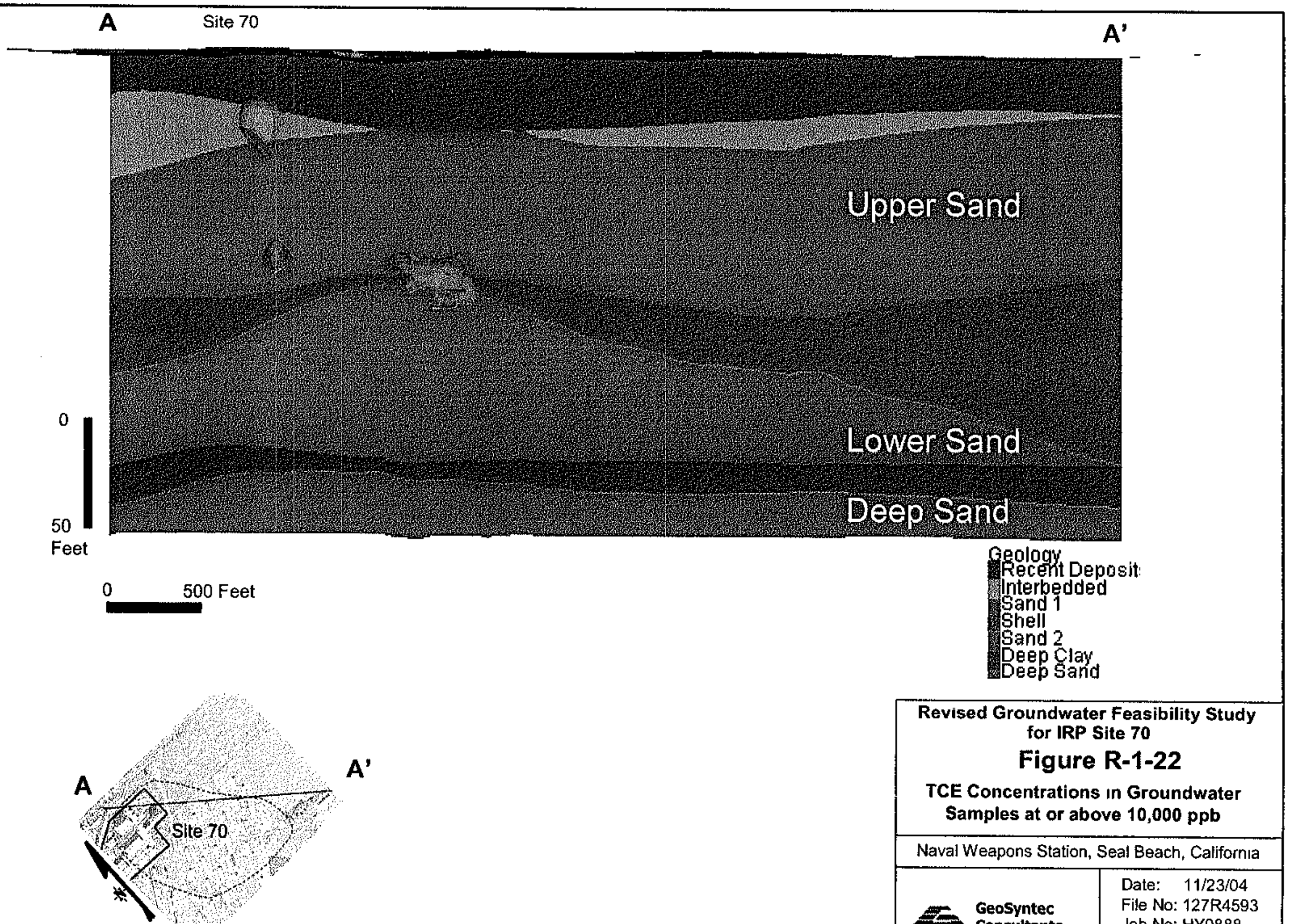
Figure R-1-21

TCE Concentrations in Groundwater Samples at or above 50 ppb with Geology

Naval Weapons Station, Seal Beach, California

GeoSyntec Consultants

Date: 11/23/04
File No: 127R4593
Job No: HY0888
Rev No: A



Revised Groundwater Feasibility Study for IRP Site 70

Figure R-1-22

TCE Concentrations in Groundwater Samples at or above 10,000 ppb

Naval Weapons Station, Seal Beach, California

GeoSyntec Consultants

Date: 11/23/04
File No: 127R4593
Job No: HY0888
Rev No: A

- Appendix R-B documents ARARs, including the new ARARs list provided by DBC - 19 January 2005.
- Appendix R-C provides detailed descriptions of remedial process options evaluated in the FS.
- Appendix R-D describes the development of cost estimates for remedial alternatives considered in this FS and provides detailed costs for each alternative analyzed in Section 5.
- Appendix R-E presents the results of groundwater modeling studies used to evaluate various remedial options.
- Attachment A provides referenced tables and figures from the original FS (BNI, 2002).

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Section R-2
REMEDIAL ACTION OBJECTIVES

This section presents the RAOs for VOC-contaminated groundwater at IR Site 70. Factors considered in determining RAOs included affected media, constituents of concern (COCs), human health and ecological risks, and ARARs.

U.S. EPA defines *remedial action objectives* as media-specific goals for protecting human health and the environment (U.S. EPA 1988). As stated in the NCP, RAOs focus the FS and define the scope of potential cleanup activities, thereby guiding the development and evaluation of cleanup alternatives (40 CFR 300.430[e][2][i].

General response objectives are used to identify COCs and RAOs. The general response objectives for IR Site 70 are as follows:

- Consistent with U.S. EPA, SWRCB, and RWQCB policies and regulations, protect existing beneficial uses of the shallow aquifer underlying NAVWPNSTA Seal Beach to the extent practicable while preventing or minimizing off-base migration of VOC contamination (as defined by RAOs).
- Protect human health by preventing extraction of VOC-impacted shallow groundwater for domestic use until RAOs are achieved.

R-2.1 AFFECTED MEDIA AND CONSITUENTS OF CONCERN

Sampling results from the ERSE and previous investigations have shown that groundwater is impacted by VOCs at and downgradient of IR Site 70. Hence, VOCs in groundwater (i.e., the affected media) are the COCs for this RFS.

The COCs were identified based on ERSE findings (Table 2-2, Attachment A). Considered were the tap water carcinogenic risk resulting from the screening risk calculations and the frequency of occurrence, distribution, and overall mass of the COPCs. Table 2-4 (Attachment A) lists total mass of the major constituents at IR Site 70. These estimates were developed from ERSE data (BNI, 1999a) and groundwater modeling results (Appendix R-E).

2.1.1 IR Site 40

R-2.1.2 IR Site 70

Four chlorinated VOCs are COCs at IR Site 70: 1,1-dichloroethene, TCE, vinyl chloride, and chloroform (Table 2-2, Attachment A). The remedial technologies have been evaluated based on their ability to address these VOCs.

These constituents were identified based on their contribution to the screening-level carcinogenic risk for tap water and frequency of occurrence at the site. The total cancer risk associated with groundwater at IR Site 70 was estimated at 1.2 X 10^{-1} by using U.S. EPA tap water PRGs. Chlorinated VOCs contribute 98.5 percent of the total carcinogenic risk (BNI, 1999a).

Although ERSE sampling results showed metals exceeding background levels (BNI, 1999a), metals were ruled out as COCs at IR Site 70 because:

- metals are concentrated in the heavy use areas of the RT&E facility;
- single occurrences of metals reported above the statistical background were isolated;
- naturally occurring metals, such as copper, iron, manganese, and arsenic, are widespread, and their range of concentrations can largely be attributed to various organic and inorganic adsorption mechanisms; and
- the cancer and noncancer risk drivers at IR Site 70 are overwhelmingly chlorinated VOCs.

For the purposes of this RFS, the area to be addressed corresponds to the footprint of the TCE plume at IR Site 70 (Figures R-1-18 through R-1-21). Because of the levels of contamination encountered, the affected media (i.e., groundwater) will be addressed as two separate areas within the plume: *a suspected dense nonaqueous-phase liquid (DNAPL) area* and a *dissolved-phase plume*.

Figure 2-1 (Attachment A) shows the suspected DNAPL area. This area corresponds to the 10,000 μg/L isocontour of TCE at the less-than-35-foot depth interval (Figure R-1-22). It is assumed to extend to approximately 50 feet bgs. The corresponding area at the surface is approximately 5,700 square feet, and the total volume (all media) is approximately 285,000 cubic feet (10,600 cubic yards). The area of the dissolved-phase plume is approximately 2,500 by 1,000 feet at its largest footprint in the 75- to 110-foot-bgs depth interval (Figure R-1-18).

2.2 POTENTIAL RECEPTORS/EXPOSURE PATHWAYS

R-2.3 APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

ARARs are used to develop remediation (i.e., cleanup) goals for the groundwater affected by VOCs at IR Site 70. Remedial response actions at these sites will be governed by state and federal ARARs that provide criteria for establishing numerical cleanup goals for groundwater and for potential discharge to surface waters. Because the ocean is located near the base, substantive provisions of the California Ocean Plan (SWRCB 1997) (as referenced in the Water Quality Control Plan, Santa Ana Basin [RWQCB, 1995]) may constitute ARARs for any response action establishing criteria/standards controlling discharge of wastes into ocean waters (or conduits to ocean waters).

As part of the FS, the NCP requires comparison of constituent concentrations in the media of interest to acceptable concentrations. Acceptable concentrations are established by federal and state ARARs as set forth in remediation goals. This comparison typically includes an evaluation of whether:

- the remediation goals for the COCs sufficiently protect receptors at the site; and

- the exposure analysis conducted as part of the risk assessment adequately addresses each significant pathway to receptors.

Remediation goals serve as endpoints for the response action, establishing both the performance requirements for remedial technologies and a basis for measuring the success of cleanup. Under CERCLA, remediation goals are typically established by using health-based ARARs when available. When health-based ARARs are not available, or are not sufficiently protective due to multiple exposures or multiple constituents, remediation goals can be set by using site-specific risk calculations or other risk-based criteria. The development of remediation goals for groundwater should also consider the background quality of the water as well as its ability to affect other groundwater and surface water (e.g., through migration or discharge).

CERCLA remedial actions for contaminated groundwater are based on the expectation that aquifers will be returned to beneficial uses wherever practicable (40 CFR 300.430[a]][1][iii][F]. However, shallow groundwater beneath NAVWPNSTA Seal Beach is not currently used for municipal/domestic beneficial use. Potential discharge of contaminated groundwater to surface waters is the primary pathway for risks to the environment. Therefore, the remediation goals for groundwater are based on preventing potential human and ecological exposure to groundwater containing VOCs above health-protective levels and protecting existing beneficial uses while preventing or minimizing off-base migration of VOCs (as defined by RAOs).

In developing remediation goals for IR Site 70, the substantive provisions of the following requirements were identified as ARARs:

- Clean Water Act for discharge to surface water in 40 CFR 257.3-3(a);
- federal MCLs and nonzero maximum contaminant level goals for VOCs;
- state primary MCLs for VOCs in Title 22 *California Code of Regulations* (CCR);
- Water Quality Control Plan, Santa Ana River Basin (water quality objectives, beneficial uses, waste discharge limitations, and subsequent amendments to the WQCP including R8-2004-0001) (RWQCB, 1995);
- California Ocean Plan (SWRCB, 1997); and
- RCRA groundwater protection standards in CCR Title 22 Section 66246.94(a)(1), (a)(3), (c), (d), and (e).

See Appendix R-B for details on how remediation goals and ARARs were identified. Remediation goals may change based on input from state agencies and the community on technological limitations and performance data identified during remedy implementation.

R-2.4 REMEDIAL ACTION OBJECTIVES FOR IR SITE 70

RAOs are site-specific, qualitative goals that define the purpose of site cleanup. RAOs specify:

- COCs;
- exposure route(s) and receptor(s); and
- an acceptable contaminant level or range of levels for each exposure route (i.e., a remediation goal).

Because RAOs typically involve preserving or restoring a resource (e.g., groundwater, surface soil, they are expressed in terms of the medium of interest and target cleanup levels whenever possible. The groundwater COCs are limited to chlorinated VOCs (primarily TCE) at IR Site 70. RAOs were identified as the result of the ARARs analysis (Appendix R-B).

The RAOs for IR Site 70 focus on mitigating potential human exposures to the groundwater and limiting the further degradation (DNAPL mobilization) and migration of VOCs in the groundwater or off base (Table 2-6, Attachment A)

While MCLs have generally been established as PRGs for the purposes of this FS, this should not be construed as an acceptance by the DON of final remediation goals at IR Site 70. The DON believes establishing final remediation goals is an iterative process, taking into account site-specific factors such as aquifer classification and designated use, and the site- and chemical-specific nature of the groundwater requiring remedial action.

According to U.S. EPA (1989), in many cases, groundwater response actions should be initiated even though it is not possible to assess the restoration timeframe or ultimate contaminant concentrations achievable. U.S. EPA further concluded that after groundwater remediation systems have been operated and monitored over time, it should be possible to define the final goals of the action.

Particularly for the DNAPL area at IR Site 70, because of the site-specific conditions, the DON believes that ARARs waivers listed in the NCP (§300.430[f][1][ii][C] may be a necessary component of the final remedy (U.S. EPA 1993a). At IR Site 70, DNAPLs (in the form of ganglia or droplets) are presumed to exist; therefore, the DON is evaluating a "containment zone" approach to site cleanup at this location. State containment zone provisions, including 23 CCR Division 3, Chapter 22 Section 2911, are potentially applicable.

Section R-3
IDENTIFICATION AND SCREENING OF REMEDIAL TECHNOLOGIES

This section discusses general response actions and associated technologies capable of addressing VOC-contaminated groundwater at IR Site 70. The remedial technologies have been screened for effectiveness, implementability, and relative cost (U.S. EPA 1988). Technologies retained after screening evaluation have been assembled into remedial alternatives (Section R-4).

R-3.1 GENERAL RESPONSE ACTIONS

General response actions are broad categories of remedial approaches for RAOs. Some response actions may stand alone as complete remedial alternatives. However, in most cases, combinations of response actions are required to effectively address site-related contamination and meet all the RAOs.

Potential general response actions were developed because the NCP requires consideration of a broad range of alternatives. Per 40 CFR 300.430(e), an FS must evaluate no action; source control alternatives that reflect varying degrees of treatment, containment, and institutional controls; and groundwater restoration alternatives that attain RAOs within different time periods using one or more different technologies.

For this FS, the following general response actions were considered.

- **No action**
- **Institutional controls**
- **Monitoring** may include technical measures such as groundwater sampling and analysis to evaluate VOC extent and migration, potential risks, and/or changes in site conditions over time.
- **Monitored natural attenuation** relies on naturally occurring *in situ* processes (e.g., biodegradation, chemical transformation, volatilization, dilution, dispersion, and adsorption) to achieve remediation goals within a reasonable timeframe (U.S. EPA 1999). Under certain conditions, these natural processes act to reduce the mass, toxicity, mobility, or volume of VOC-contaminated soil and groundwater. Monitoring is necessary to check cleanup progress.
- **Containment**
- ***In situ* treatment** involves using in-place processes (e.g., biological, physical, thermal, or chemical). Biological, thermal, physical, or chemical processes may be used to break down contaminants and/or alter their properties so they can be easily extracted.
- **Extraction**
- ***Ex situ* treatment**
- **Disposal**
- **Treatment of vapor-phase VOCs**

- **Enhanced bioremediation** technologies provide for *in situ* treatment of the COCs. The technologies can include biostimulation of intrinsic microorganisms or bioaugmentation of halorespiring microorganisms to initiate the bioremediation.

R-3.2 IDENTIFICATION OF REMEDIAL TECHNOLOGIES

Technologies were identified for the general response actions with the RFS options highlighted. Technologies included those based on guidance on presumptive remedies. Other selected technologies were included after reviewing site-specific conditions (Table R3-1). Appendix R-C describes the technologies in detail.

Presumptive remedies are technologies presumptively the most appropriate for addressing contamination at sites affected by chlorinated VOCs in soil and groundwater (U.S. EPA 1993a; 1996; 1997a). U.S. EPA expects presumptive remedies to be used at all appropriate sites, although alternative technologies may be considered when warranted (U.S. EPA 1993b). To that end, U.S. EPA has published several guidance documents, directives, and policy statements, which were followed for this FS (U.S. EPA 1994a; 1997a,b). Based on the DON guidelines for optimizing remedial actions all plans for installing pump and treat systems on Navy and Marine Corps installations require approval from Naval Facilities Engineering Command headquarters (DON, 2004). This RFS evaluates bioremediation *in lieu* of a pump and treat approach for the dissolved phase plume and source area.

R-3.3 SCREENING OF REMEDIAL TECHNOLOGIES

For each remedial technology, associated process options are identified. Appendix R-C provides detailed descriptions of the enhanced bioremediation process options. Remediation technologies and associated process options were then screened for effectiveness, implementability, and cost (Section R-3.3.1). The objective of screening was to select representative process options for each technology, then use selected technologies to form remedial alternatives, thus simplifying development and evaluation of alternatives (Section R-4).

Process options were screened for two areas of interest: dissolved-phase plume at IR Site 70, and the suspected DNAPL source area at IR Site 70.

R-3.3.1 Screening Criteria

The process option screening criteria (effectiveness, implementability, and cost) were applied based on their relative importance to the FS process (U.S. EPA 1988). The criterion of effectiveness was given the most weight, followed by implementability, then cost. When two or more process options yielded comparable results, cost determined the most effective option.

Table R-3-1
Identification of Remedial Process Options

General Response Action	Remedial Technology	Process Option *
No action	None	None
Institutional controls	Land-use controls Water-use controls	Land-use controls Water-use controls
Monitoring	Monitoring	Groundwater sampling and analysis
Monitored natural attenuation	Monitored natural attenuation	Natural attenuation
Containment	Vertical barriers	Sheet piling
		Grout curtains
		Deep soil mixing
		Slurry wall
	Hydraulic controls	Extraction/injection
In situ treatment	Biological treatment	Anaerobic biodegradation
	Biological treatment	Anaerobic biodegradation with bioaugmentation
	Physical treatment	Air sparging
	Thermal treatment	Electrical resistive heating
		Steam stripping
	Chemical treatment	*In situ* flushing
		Permeable reaction walls
		Chemical oxidation
Extraction	Groundwater extraction	Wells
		Directional wells
		Vacuum-enhanced extraction
	Fracturing	Fracturing
Ex situ treatment	Biological treatment	Bioreactors
	Physical treatment	Air stripping
		Carbon adsorption
	Chemical treatment	Ultraviolet oxidation
Disposal	Off-site disposal	RCRA TSD facility
	Groundwater discharge	Injection/Infiltration
		Publicly owned treatment works
		Surface outfall
		Beneficial uses
Vapor-phase VOC Treatment	Physical treatment	Vapor-phase carbon adsorption

Acronyms/Abbreviations:
RCRA – Resource Conservation and Recovery Act
TSD – treatment, storage, and disposal
VOC – volatile organic compound

Highlighted Text Reflects Remedial Alternatives Evaluated Within the RFS
* Options from Original FS (BNI, 2002)

The following was considered when screening for **effectiveness** (U.S. EPA 1988).

- *Ability to achieve RAOs for the protection of human health and the environment.* Not considered further were technologies incapable of attaining chemical-specific ARARs or health-based remediation goals or those that would not effectively contribute to the protection of public health or the environment.
- *Permanent reduction in toxicity, mobility, or volume of VOCs in affected groundwater and soil.* Preferred were technologies that permanently reduce contaminant toxicity, mobility, or volume.
- *Long-term risks of treatment residuals or containment systems.* Preferred were technologies with significantly lower long-term risks.
- *Risks to the public, workers, or the environment during technology implementation.* Preferred were technologies posing less risk during implementation.

The following was considered when screening for **implementability** (U.S. EPA 1988).

- *Site characteristics limiting the construction or effective functioning of a technology.* Eliminated were technologies limited by site conditions.
- *Waste or media characteristics that limit the use or effective functioning of a technology.* Eliminated were technologies limited by waste or media characteristics.
- *Availability of equipment needed to implement a technology along with the capacity of any off-site treatment or disposal facilities required.* Preferred were commercially-developed technologies that are readily available or innovative technologies that have been pilot-tested.
- *Administrative feasibility of obtaining permits and approvals from regulatory agencies and other offices.* Such feasibility is an important component of implementability, because a technically feasible option may be difficult or impossible to permit. Technologies were eliminated if permitting was judged to be inordinately difficult

Cost criteria used to screen remedial technologies were qualitative and based on engineering judgment unless otherwise noted. The relative magnitude of capital as well as operation and maintenance (O&M) costs were considered when comparing process options within a technology. Process options with lower costs were preferred if the effectiveness and other implementability criteria were similar. To allow a more accurate comparison of 1999 costs to 2005 costs, a 3 percent escalation per year was used.

R-3.3.2 Screening Results

The following subsections discuss screening results for only components of the RFS. Results for process options are grouped by general response action (Section R-3.1) and technology. Table R3-2 summarizes results and lists process options retained for alternatives development (Section R-4). See Appendix R-C for details on process options. In the following section, the general headings for the technologies considered are provided with the understanding that the detailed discussion for these sections are in the original FS.

3.3.2.1 NO ACTION

3.3.2.2 INSTITUTIONAL CONTROLS (RETAINED AS STATED IN ORIGINAL FS)

R-3.3.2.3 MONITORING

Monitoring involves regular site inspections, groundwater monitoring, and compliance reporting. Monitoring will be a significant factor in evaluating the effectiveness of the proposed *in situ* enhanced bioremediation treatment. One process option, groundwater sampling and analysis, was screened. Groundwater would be periodically sampled and analyzed to monitor aquifer hydraulics, effectiveness of enhanced bioremediation, variations in contaminants, and aquifer chemistry (Appendix R-C).

- ***Effectiveness:*** Groundwater sampling and analysis as a stand-alone action is not effective at reducing the mass, volume, or toxicity of groundwater contamination. It is effective as a means of monitoring the effectiveness of groundwater remediation measures. However, groundwater sampling and analysis may not be capable of distinguishing between contaminant concentrations attributable to dissolved-phase contamination and nonaqueous-phase contamination.
- ***Implementability:*** Groundwater sampling and analysis is implementable at NAVWPNSTA Seal Beach as demonstrated by previous investigations.
- ***Cost:*** Groundwater sampling and analysis can be cost effective if planned and executed effectively and if it is fixed in duration.

This process option is retained to be used in combination with other technologies for the IR Site 70 dissolved plumes and the IR Site 70 DNAPL area. Data quality objectives should be carefully reviewed for any sampling and analysis performed in the suspected DNAPL area at IR Site 70.

Table R-3-2
Remedial Process Option Screening Results

General Response Action	Remedial Technology	Process Option[a]
No action	None	**None**
Institutional controls	Land-use controls Water-use controls	**Land-use controls** **Water-use controls**
Monitoring	Monitoring	**Groundwater sampling and analysis**
Monitored natural attenuation	Monitored natural attenuation	**Natural attenuation**
Containment	Vertical barriers	Sheet piling
		Grout curtains
		Deep soil mixing
		Slurry wall
	Hydraulic controls	**Extraction/injection**
In situ treatment	Biological treatment	**Anaerobic biodegradation**[b]
	Biological treatment	**Anaerobic biodegradation coupled with bioaugmentation**
	Physical treatment	Air sparging
	Thermal treatment	Electrical resistive heating
		Steam stripping
	Chemical treatment	*In situ* flushing
		Permeable reaction walls
		Chemical oxidation[c]
Extraction	Groundwater extraction	**Wells**
		Directional wells
		Vacuum-enhanced extraction
	Fracturing	Fracturing
Ex situ treatment	Biological treatment	Bioreactors
	Physical treatment	Air stripping
		Carbon adsorption
	Chemical treatment	Ultraviolet oxidation
Disposal	Off-site disposal	RCRA TSD facility
	Groundwater discharge	Injection/infiltration
		Publicly owned treatment works
		Surface outfall
		Beneficial uses
Vapor-phase VOC treatment	Physical treatment	Vapor-phase carbon adsorption

Notes:
[a] bold print indicates retained process option;
shading indicates process option is not retained;
underline indicates process option evaluated in the RFS
[b] IR Site 70 Source Area and Dissolved Plume
[c] IR Site 40 and IR Site 70 DNAPL area only

Acronyms/Abbreviations:
DNAPL – dense nonaqueous-phase liquid
IR – Installation Restoration (Program)
RCRA – Resource Conservation and Recovery Act
TSD – treatment, storage, and disposal
VOC – volatile organic compounds

R-3.3.2.4 MONITORED NATURAL ATTENUATION

Monitored natural attenuation (MNA) allows natural processes to reduce contamination over time. Monitoring is necessary to verify that these processes reduce contaminant concentrations to acceptable levels. MNA combines the groundwater sampling and analysis process option (Section R-3.3.2.3) with the process option of natural attenuation. A site-specific evaluation of natural attenuation concluded that there is evidence of partial natural attenuation occurring in selected areas of the contaminant plumes (Parsons 1998).

- ***Effectiveness:*** Parsons (1998) strongly suggests biodegradation via reductive dechlorination is occurring at IR Site 70 and that conditions below 100 feet bgs at IR Site 70 were favorable toward reductive dechlorination. The study was inconclusive regarding the potential for natural attenuation in shallower groundwater at IR Site 70. Therefore, natural attenuation may be effective as a stand-alone process or for selected portions of the contaminant plumes. Natural attenuation may be effective in reducing contaminant concentrations; however, it may require long periods of time to achieve remediation goals in some cases.
- ***Implementability:*** Implementability of natural attenuation varies depending on the location within the contaminant plumes. The primary limitation on natural attenuation is that it is controlled by ambient flow conditions in the subsurface. Heterogeneity of aquifer materials also complicates both the extent and rate of natural attenuation processes. The Parsons study (1998) suggests natural attenuation is implementable in selected areas, based on evidence that reducing conditions are prevalent in at least some portions of the affected aquifer.
- ***Cost:*** Natural attenuation is a low-cost alternative for addressing groundwater contamination, assuming it is effective.

This process option was retained for the IR Site 70 dissolved plumes and the IR Site 70 DNAPL area. The DON has recently instituted a long-term groundwater monitoring program at IR Site 70; this program should provide additional information to evaluate natural attenuation as a process option.

3.3.2.5 CONTAINMENT

R-3.3.2.6 *IN SITU* TREATMENT

Treatment *in situ* is accomplished without removing contaminated groundwater from the geologic formation.

Biological Treatment Including Biostimulation and Bioaugmentation

In situ bioremediation can be achieved by the addition of suitable electron donors to stimulate indigenous halorespiring microorganisms to completely dechlorinate (i.e., through reductive dechlorination) the site COCs to ethene. Bioaugmentation with cultures containing halorespiring bacteria is required when the requisite bacteria are absent or too poorly distributed to allow bioremediation to achieve complete dechlorination to non-toxic end-products and to meet remedial goals in a timely fashion. Recent discoveries that key halorespiring bacteria can dechlorinate compounds like PCE and TCE at their aqueous solubilities have dispelled myths that bioremediation of DNAPL source areas was not a viable approach. Both laboratory and field applications of bioremediation have shown that this technology increases the rate of DNAPL removal and thereby shortens the clean up times of sources.

Additional supporting information and studies demonstrating the effectiveness of bioremediation approaches are provided in Appendix R-C.

The use of emulsified vegetable oil (EVO), lactate, and other electron donor compounds has been shown to accelerate anaerobic reductive dechlorination. The *in situ* bioremediation of DNAPL and biobarrier treatment of dissolved phase plumes are innovative applications of the proven bioremediation process. Optimization of the treatment approach may require limited pilot-scale testing, remedial design investigation to define key factors for enhanced bioremediation, and/or microcosm studies to define specific design elements of the treatment system.

The principal features of the enhanced bioremediation remedy will be the use of slow release electron donors (e.g., EVO) placed in transects to create biobarriers across the dissolved phase plume and a grid of donor injection points for the source area (DNAPL area). The enhanced bioremediation process will be evaluated as Alternative 11 in the RFS.

Biobarriers will be used to segment the groundwater plume into treatment zones, because it is cost- prohibitive to attempt to deliver electron donors or culture throughout the large volume of contaminated groundwater at the site. Treated groundwater emanating from a biobarrier will sweep contaminated groundwater into the next downgradient biobarrier. The spacing between the biobarriers, and the natural attenuation rate, will set the total cleanup time of the dissolved phase plume. Bioaugmentation of the source area and the biobarriers with a stable, halorespiring culture (e.g., KB-1™) will likely be required and is recommended to overcome uncertainties regarding the potential of indigenous microorganisms to meet remedial goals within desired timeframes. The use of food-grade vegetable oil will provide a long-lasting, slow-release electron donor for the biostimulation of intrinsic or bioaugmented microorganisms. The EVO is commercially-available and delivered in drums or tote bags. The EVO is blended with existing site groundwater as it is injected into the aquifer for the creation of biobarriers or treatment of the source zone.

Demonstration projects for this approach include test plots at Dover AFB, Launch Complex 34 (an EPA SITE Demonstration project, [EPA, 2004]), and at a commercial Long Beach California facility. In addition, SWDIV and NWSSB have completed a pilot test at IR Site 40 that demonstrates the effective dechlorination of VOCs after the injection of the KB-1™ culture. These and additional studies indicate that the bioremediation technology is viable for this site. The technical approach for this site is considered an innovative application of proven technologies.

- *Effectiveness:* This technology is proven to be effective at removing chlorinated VOCs to below RAO provided that: (1) conditions are conducive to reductive dechlorination, which can exist naturally or be engineered through the addition of electron donors; and *Dehalococcoides ethenogenes* strains capable of further dechlorination of cis-DCE to ethene must be present. The KB-1™ culture contains strains of *Dehalococcoides* that have been demonstrated to degrade the daughter products (cis-DCE, vinyl chloride, etc.) under field conditions, including Site 40 NWSSB (BNI, 2004a; EPA, 2004). This technology has been shown to be effective in permeable formations ranging from fractured bedrock and sands to silts. Microcosm and bench scale testing would provide data to support the effectiveness of the technology and to provide data on the best combination of electron donors.
  - **IR Site 70 dissolved-phase plume.** The potential for dechlorination by using biostimulation and bioaugmentation is supported based on initial observations of VOC distribution in the source and dissolved plume areas at the IR Site 70 (Parsons 1998). The evidence of dechlorination daughter products within the shallow source zone indicates that anaerobic dechlorination was possibly taking place prior to the remedial investigation. Subsequent aerobic pilot tests may have stalled or terminated these processes. Dechlorination daughter products were observed to a lesser degree in the deeper zones (beneath 80 feet bgs). Application of an electron donor, such as EVO, to stimulate indigenous microorganisms may be effective within these areas, and addition of stable halorespiring microorganisms would likely enhance the effectiveness of this approach. Creation of a biobarrier at the site is a passive remediation approach, requiring only periodic addition of the EVO. The culture used for bioaugmentation would only be added once.
  - **IR Site 70 DNAPL source area.** Laboratory and field demonstrations and applications provide clear indication that anaerobic bioremediation using bioaugmentation is an effective process to treat DNAPLs. These tests have been documented by the US EPA Superfund Innovative Technology Evaluation (SITE) Program (EPA, 2004) and other tests at Federal facilities (BNI, 2004a). High concentrations of chlorinated VOCs associated with source areas have been found to be ideal niches for halorespiring microorganisms, because the high concentrations suppress the growth of other microorganisms that may compete for the added electron donor. Therefore, electron donors are more efficiently used and directed towards reductive dechlorination in source areas.
- ***Implementability:*** This technology is readily implementable, requiring only the use of injection wells or direct push probes to inject electron donors or microbial cultures. Electron donors and bioaugmentation cultures are commercially-available and are delivered on site in appropriate containers suitable for blending and injection. Microbial activity may result in changes in secondary water quality, which must be factored into the remedial design; however, most impacts dissipate within a short distance of the biobarriers and source areas due to natural processes. A factor that affects the design and cost is

the flux of other potential electron acceptors (e.g., sulfate), as they can affect the rate of consumption of the electron donors and the frequency of replenishment. Operational issues include potential fouling of injection wells due to microbial growth and precipitation of inorganic constituents. However, these potential impacts can be more than offset by the passive nature of the remedial process when the implementation is designed to meet the site constraints.

- **IR Site 70 dissolved-phase plume.** The depth of contamination in some areas increases the difficulty in implementation. The higher permeability of these zones as evidenced by the aquifer test results and high estimated pumping rate allows effective distribution of electron donor and added microorganisms.
- **IR Site 70 DNAPL source area.** It would be technically feasible to implement electron donor injection and bioaugmentation except possibly in the upper clay layer. Drill rig access may be a problem in some areas; so directional drilling may be necessary The presence of sulfate may need to be addressed. During the remedial design investigation, the Navy will evaluate potential geochemical interactions within the source zone DNAPL and intrinsic minerals within the soil. Use of KB-1™ culture should provide for complete dechlorination of the daughter products. Monitoring of the treatment system effect should allow confirmation of these results.

- *Cost:* Factors affecting cost include the quantity of electron donor (e.g., EVO) and KB-1™ culture required, delivery system requirements (e.g., well spacing, well depth, biobarrier spacing, etc.), and monitoring to evaluate and confirm the performance standards.
  - **IR Site 70 dissolved-phase plume.** Implementing enhanced bioremediation would be moderate in cost when contrasted with the volume of water being treated. By using the biobarrier approach, the plume is segmented into treatment cells. The spacing of the biobarriers directly affects the time to complete remediation. The need for extensive monitoring to evaluate the treatment design and monitor the plume dynamics contributes to the cost. Recirculation of groundwater during addition of the electron donor to achieve its proper dispersion adds slightly to the cost of the delivery system.
  - **IR Site 70 DNAPL source area.** Implementing enhanced bioremediation through either biostimulation and/or bioaugmentation is a relatively passive process. The initial injection and each subsequent electron donor injection are labor-intensive but occur once every two years. Drill rig access and competing electron acceptors would affect cost. Monitoring the effectiveness of the system will impact costs. Pumping of site groundwater to make up the injected electron donor emulsion will also add slightly to the yearly operational costs.

This process was retained for IR Site 70 Plume characteristics are amenable to treatment. ERSE data indicate the subsurface environment is carbon-deficient and hence, electron donor enhancement could be effective in accelerating natural anaerobic biodegradation. The SWDIV study at Seal Beach IR Site 40 is promising and translates well to conditions at IR Site 70, because both plumes are relatively slow-moving and both plumes are relatively brackish and conducive to anaerobic biodegradation. Complete dechlorination was achieved at Seal Beach NWS Site 40 under anaerobic conditions (BNI, 2004a). Effective demonstrations of enhanced bioremediation have been completed at NASA Launch Complex 34 and were documented in the EPA SITE program (EPA, 2004).

The use of enhanced bioremediation within biobarriers is an innovative application but is not without proven results. The proposed approach allows segmenting the plume into treatment zones with set cycle times based on the biobarrier spacing and groundwater flow rate. The biobarrier technology is currently being employed at several sites throughout the United States. Key factors to the success of the technology include proper definition of the aquifer characteristics, well construction, and injection approach.

3.3.2.7 EXTRACTION

3.3.2.8 *EX SITU* TREATMENT

3.3.2.9 DISPOSAL

3.3.2.10 VAPOR-PHASE VOC TREATMENT

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Section R-4
DEVELOPMENT AND SCREENING OF REMEDIAL ALTERNATIVES

The RFS for IR Site 70 discusses the new Alternative 11 and, by reference, includes the existing FS (BNI, 2002) discussion of Alternatives 1 through 10. Technologies and associated process options retained after screening (Section R-3) have been assembled into comprehensive remedial alternatives for IR Site 70. Many of the alternatives involve a combination of the general response actions (Section R-3.1). The alternatives represent a range of technically feasible remedial responses to address IR Site 70 specific groundwater contamination. These alternatives were screened based on effectiveness, implementability, and cost before conducting a detailed analysis to reduce the number of alternatives to a manageable number.

This revised Section R-4.1 describes the new remedial alternative. Revised Section R-4.2 discusses criteria specified in CERCLA and the NCP and gives screening results for the new Alternative 11.

R-4.1 DEVELOPMENT OF REVISED REMEDIAL ACTION ALTERNATIVE

A revised remedial alternative (11) for IR Site 70 was developed based on RAOs (Section 2) and according to requirements of CERCLA, the NCP, and, to the extent practicable, U.S. EPA technical guidance (U.S. EPA 1988). In addition, the revised approach addresses issues in response to a Department of Navy directive for optimizing remedial actions. CERCLA Section 121(b) identifies the following statutory preferences for remedial actions.

- Preferred remedial actions are those involving treatment that permanently and significantly reduce the volume, toxicity, or mobility of site-related contaminants.
- The least favorable remedial action is off-site transport and disposal of hazardous substances or contaminated materials without treatment when practical treatment technologies are available.
- Remedial actions using permanent solutions, alternative treatment technologies, or resource recovery technologies should be assessed.

The NCP states that the FS should develop a range of remedial alternatives (40 CFR 300.430[e]). The RFS provides an evaluation based on advancements in the enhanced bioremediation field. Alternative 11 provides treatment through destruction of the chlorinated compounds at this site. The CERCLA guidance directs that these alternatives may vary in the degree of treatment employed (i.e., in the quantity of material treated or the percent reduction of contaminants) as well as in the types and quantities of residuals and untreated material remaining on-site requiring long-term management. For groundwater response actions, the FS may also consider alternatives that attain remediation goals in varying lengths of time using one or more technologies.

Also considered were the criteria regarding eventual selection of a preferred remedial action (U.S. EPA 1988). According to U.S. EPA technical guidance, the preferred remedial action for IR Site 70 should:

- protect human health and the environment;
- meet contaminant-specific ARARs and be consistent with location- and action-specific ARARs;
- be cost-effective;
- use permanent solutions and alternative treatment technologies to the maximum extent practicable; and
- satisfy the preference for treatment as a principal element of the remedial action to reduce the toxicity, mobility, or volume of contaminants.

The RFS includes, by reference, the existing FS (BNI, 2002) alternatives that do not involve treatment. In these cases, human health and the environment would be protected by using engineering controls to prevent or control exposure to site contaminants. As necessary, institutional controls (i.e., land-use controls or water-use controls) would be included as part of a comprehensive remedial alternative to ensure continued effectiveness of engineering controls and other aspects of the response action.

4.1.1 Remedial Alternatives – IR Site 40

4.1.1.1 ALTERNATIVE 1 – NO ACTION

4.1.1.2 ALTERNATIVE 2 – MNA

4.1.1.3 ALTERNATIVE 3 – HYDRAULIC CONTAINMENT

4.1.1.4 ALTERNATIVE 4 – PUMP AND TREAT

4.1.1.5 ALTERNATIVE 5 – *IN SITU* TREATMENT

R-4.1.2 Additional Remedial Alternative – IR Site 70

This section presents an additional remedial alternative for IR Site 70. The existing FS (BNI, 2002) includes the discussion of the original accepted alternatives. This section will discuss the new Alternative 11 for the source area (DNAPL) and the dissolved phase plume. Alternative 11, enhanced bioremediation, provides a feasible process for addressing both the suspected DNAPL area, where dispersed DNAPL droplets/ganglia may exist, and the dissolved plume.

Alternative 11 is discussed separately for the suspected DNAPL area and for the dissolved plume. These alternatives are combined to create sitewide alternatives (Section 4.1.2.3).

R-4.1.2.1 SUSPECTED DNAPL SOURCE AREA

The site investigation indicated the potential presence of dispersed DNAPL droplets/ganglia in the source area. Alternative 11, an *in situ* enhanced bioremediation approach, has been developed for the suspected DNAPL source area and includes:

- Alternative 11SA, biostimulation with electron donor; and
- Alternative 11SB, biostimulation followed with bioaugmentation.

These alternatives are designated "S" to differentiate them from the dissolved-plume alternative. All of the alternatives include institutional controls, groundwater monitoring, and MNA (as needed) as a component.

Alternative 11SA-Biostimulation

For this alternative, biostimulation of the intrinsic halorespiring microorganisms with an electron donor (Emulsified Vegetable Oil [EVO]) would address the suspected DNAPL area. Biodegradation rates of chlorinated VOCs have been shown to enhance the dissolution rate of DNAPLs, thereby shortening the time for site cleanup and containing the dissolved phase (i.e., flux reduction) emanating from DNAPL sources. EVO would be introduced through a grid of wells starting around the perimeter of the DNAPL area and gradually applying the electron donor over the source area. EVO would also be injected into a biobarrier aligned along the northern edge of the source area to contain and treat TCE mass discharge from the source area under conditions of groundwater flow reversal. The EVO would be reinjected as it is consumed (estimated every 2 years). The EVO will be injected at low concentrations (targeting oil saturations of 1%) to avoid adversely impacting soil permeability. Growth and distribution of the indigenous halorespiring microorganisms, and trends of the VOCs and their degradation products, and other parameters (e.g., key inorganic species, dissolved hydrocarbon gases, dissolved oxygen, oxidation-reduction potential), would be monitored. Sampling would occur within and downgradient of the source zone as part of the remediation monitoring program (RMP) to evaluate the enhanced mass removal rate of the residual DNAPL and effectiveness of biocontainment of the source zone (i.e., reduction in total flux of chlorinated VOCs). The types, presence, and distribution of halorespiring microorganisms would be assessed through analysis of extracted DNA from groundwater or soil samples and the use of microcosms, as appropriate. MNA would be implemented when the flux of dissolved chlorinated VOCs emanating from any residual source of DNAPL is less than the assimilative capacity of the aquifer to remove these VOCs to meet RAOs.

Alternative 11SB – Biostimulation with Subsequent Bioaugmentation

This alternative is identical to Alternative 11SA but includes bioaugmentation of the groundwater with a stable, naturally-occurring, and pathogen-free culture of halorespiring microorganisms (e.g., KB-1™). The KB-1™ culture would be added shortly after the addition of EVO stimulated anaerobic conditions. The KB-1™ culture contains various strains of *Dehalococcoides ethenogenes*, which is the only microorganism capable of further dechlorinating cis-DCE past VC to ethene. Research and field demonstrations (e.g., Major *et al.*, 2002; BNI, 2004a) have shown that this microorganism or its appropriate strain is not present at all sites or is very poorly distributed and at low densities. As a result, addition of electron donors alone can lead to the accumulation of cis-DCE or VC or very long acclimation times before the effective onset of complete dechlorination to ethene. Bioaugmentation with cultures like KB-1™ alleviates these concerns. A study under the US EPA SITE program showed that bioaugmentation resulted in over 99% removal of residual DNAPLs (EPA, 2004). Similar RMP would be implemented as described for Alterative 11SA. MNA would be similarly implemented as described for Alternative 11SA.

R-4.1.2.2 DISSOLVED PLUME

Two variations to Alternative 11 have been developed for the dissolved plume:

- Alternative 11DA, Biobarriers with biostimulation,
- Alternative 11DB, Biobarriers using biostimulation with bioaugmentation.

These alternatives are designated "D" to differentiate them from suspected source area (DNAPL) alternatives. All of the alternatives would include institutional controls, MNA, and groundwater monitoring as a component.

Alternative 11DA – Biobarriers with Biostimulation

This alternative employs the stimulation of intrinsic microorganisms with electron donor (i.e., EVO) to establish biobarriers that intercept and treat the dissolved plume as it migrates under natural groundwater flow conditions. The addition of EVO will enhance the activity of indigenous halorespiring microorganisms (if present) to reductively dechlorinate the COCs to ethene. The biobarriers will be constructed by creating a continuous and immobile zone of EVO by injecting this donor through wells that transect the dissolved phase plume perpendicular to the groundwater gradient. EVO will be injected at low concentrations (target of 0.5% oil saturation) to avoid impacting soil permeability and causing avoidance of the biobarrier by the groundwater. Typical reductions in permeability are thought to be on the order of 5 to 40%, depending on the soil type, emulsion droplet size, and pore size. Given that geotechnical samples from the RI/FS indicate very well-sorted sands in the upper and lower treatment zones with minimum 30% porosities, permeability reductions for this soil type are expected to be at the lower end of the estimated range. The width of the biobarrier will be sufficient to provide the residence time necessary for the COC to be treated to meet RAOs. The EVO would be reinjected as it is consumed (estimated every 2 years). The number of biobarriers and the spacing between biobarriers will be optimized to provide the lowest cost within a reasonable treatment timeframe. COCs between biobarriers will be treated by their flushing into the next downgradient biobarrier and through natural attenuation processes that will continue to occur between biobarriers. The biobarriers will be located to contain the chlorinated plume, with biobarriers placed in the upper and lower sand unit to treat the extent of the dissolved phase plume. Monitoring wells will be placed up and downgradient of each biobarrier, and selected injection wells would be used to monitor conditions within each biobarrier. Similar monitoring parameters as described for Alternative 11SA will be used to evaluate the performance of each biobarrier.

Alternative 11DB– Biobarriers Using Biostimulation and Bioaugmentation

This Alternative is identical to Alternative 11DA but includes bioaugmentation. The culture would be similarly added as described in Alternative 11SA. Injection of the KB-1™ culture will not impact the permeability of the aquifer, as only ten liters will be amended at each injection point, which is then distributed throughout a pore volume of 3,000 ft^3 to 6,400 ft^3 (i.e., representing less than 0.01% of the pore volume). Typical full-strength bacterial populations have a population count of 10^{12} microbes per liter of groundwater; with each microbe on the order of 0.5 microns in diameter, this represents only 0.04% of the pore volume. The injected emulsified oil is also unlikely to impact soil permeability significantly for 0.5% and 1% oil saturations, with typical reductions in permeability thought to be on the order of at most 5 to 15%, depending on the soil type and pore size. Geotechnical samples from the RI/FS indicate the very well sorted sands in the upper and lower treatment zones. Porosities for these materials are expected to exceed 30 percent based on literature values. Permeability reductions for this soil type will be at the lower end of the estimated range.

R-4.1.2.3 COMBINED SITEWIDE ALTERNATIVES

Previously alternatives for the suspected DNAPL area and the dissolved plume at IR Site 70 were combined to form sitewide alternatives. The existing FS evaluated ten sitewide alternatives. The RFS addresses only the Alternative 11 approaches that have been included in Table R-4-1. The revised approach includes the use of MNA, groundwater monitoring as a support technology, and institutional controls to prevent humans from being exposed to contaminated groundwater. These revised remedial alternatives are screened in Section R-4.2.

R-4.2 SCREENING OF THE REVISED REMEDIAL ALTERNATIVE (11)

This RFS evaluates a remedial alternative (11) that has become viable based on new advances in the technology. Alternative 11 provides a two-step process that allows relatively passive remediation of both the source area and dissolved phase plume. The combination of biostimulation and bioaugmentation is significantly different from the original monitored natural attenuation approach that was evaluated in the original FS.

Alternative 11 provides a technical approach that allows for destruction of the contaminants of concern. The RFS evaluates the potential applicability of biostimulation and bioaugmentation at this site. Since the components of the treatment system are *in situ,* the impacts to the adjacent locations and operations within the plume are minimized. Based on the initial screening criteria Alternative 11 approach passed for additional review.

Table R4-1
Identification of Remedial Alternatives – IR Site 70

Alternative	Subalternative Codes	Description
1		No action
2	D1/S1	MNA (dissolved plume) and MNA (DNAPL area)
3	D1/S2	MNA (dissolved plume) and MNA/*in situ* treatment (DNAPL area)
4	D1/S3	MNA (dissolved plume) and pump and treat (DNAPL area)
5	D2/S1	Hydraulic containment (dissolved plume) and MNA (DNAPL area)
6	D2/S2	Hydraulic containment (dissolved plume) and *in situ* treatment (DNAPL area)
7	D2/S3	Hydraulic containment (dissolved plume) and pump and treat (DNAPL area)
8	D3/S1	Pump and treat (dissolved plume) and MNA (DNAPL area)
9	D3/S2	Pump and treat (dissolved plume) and *in situ* treatment (DNAPL area)
10	D3/S3	Pump and treat (dissolved plume) and pump and treat (DNAPL area)
11	SA/SB	Biostimulation of intrinsic micro organisms / bioaugmentation with halorespiring micro organism culture (DNAPL/source area)
11	DA/DB	Biobarriers with biostimulation and bioaugmentation (dissolved phase plume)

Acronyms/Abbreviations:
DNAPL – dense nonaqueous-phase liquid
IR – Installation Restoration (Program)
MNA – monitored natural attenuation

As part of the screening, alternatives are analyzed to investigate the interactions among media or, in the case of IR Site 70 areas, within the groundwater plume (i.e., the extent to which source control influences the degree of groundwater and sitewide protectiveness). For example, source control actions for sites with suspected DNAPL can influence the degree to which dissolved-phase groundwater remediation can be accomplished or the timeframe in which it can be achieved. In such cases, it may be appropriate to conduct further analyses to modify either the source control or dissolved phase groundwater response actions to achieve greater effectiveness in sitewide alternatives (U.S. EPA 1988).

Information available at the time of screening should be used primarily to identify and distinguish any differences among the various alternatives and to evaluate each alternative with respect to its effectiveness, implementability, and cost. Only the alternatives judged as the best or most promising on the basis of these evaluation factors should be retained for further consideration, unless additional information becomes available that indicates further evaluation is warranted (U.S. EPA 1988).

4.2.1 IR Site 40

R-4.2.2 IR Site 70

Table R-4-2 presents the screening results for IR Site 70. Of the eleven sitewide alternatives, six were retained for analysis (Section R-5). Screening results are summarized below.

- Alternatives that did not effectively contain and/or treat the dissolved plume were rejected; ERSE modeling indicates that the contaminant mass would continue to migrate toward potential water supply points of use unless action is taken (BNI 1999a).
- Alternatives that did not effectively contain and/or treat the suspected DNAPL area were rejected. As the result of interactions between the DNAPL area and the dissolved plume continues, these alternatives were not judged to exhibit long-term effectiveness

Table R-4-2
Revised Screening of Remedial Alternatives for IR Site 70

Alternative	Subalternative Codes	Description	Effectiveness	Implementability	Cost	Conclusion
1		No action	Not evaluated at this stage	Not evaluated at this stage	Not evaluated at this stage	Retain per the NCP
2*	D1/S1	MNA (dissolved plume) and MNA (DNAPL area)	Not effective in meeting RAOs; dissolved plume not contained	Technically feasible	Relatively low	Eliminate
3	D1/S2	MNA (dissolved plume) and MNA/*in situ* treatment (DNAPL area)	Not effective in meeting RAOs; dissolved plume not contained	Technically feasible	Relatively low in cost	Eliminate
4	D1/S3	MNA (dissolved plume) and pump and treat (DNAPL area)	Not effective in meeting RAOs; dissolved plume not contained	Technically feasible	Relatively low in cost	Eliminate
5	D2/S1	Hydraulic containment (dissolved plume) and MNA (DNAPL area)	No long-term effectiveness; DNAPL area not contained	Technically feasible	Low to moderate in cost	Eliminate
6	D2/S2	Hydraulic containment (dissolved plume) and *in situ* treatment (DNAPL area)	May be effective in permanent treatment of DNAPL; effectively contains dissolved plume	Moderate in implementability; requires bench/pilot testing	Moderate in cost	Retain
7	D2/S3	Hydraulic containment (dissolved plume) and pump and treat (DNAPL area)	Effective in containment of DNAPL area; dissolved plume	Technically feasible	Moderate in cost	Retain
8	D3/S1	Pump and treat (dissolved plume) and MNA (DNAPL area)	No long-term effectiveness; DNAPL area not contained	Technically feasible	Low to moderate in cost	Eliminate
9	D3/S2	Pump and treat (dissolved plume) and *in situ* treatment (DNAPL area)	May be effective in permanent treatment of DNAPL area; achieves containment and mass reduction of dissolved plume	Moderate in implementability; requires bench/pilot testing	Moderate to high in cost	Retain
10	D3/S3	Pump and treat (dissolved plume) and pump and treat (DNAPL area)	Effective in containment of dissolved plume and reduction of contaminant mass; effectively contains DNAPL area	Technically feasible	Moderate to high in cost	Retain
11	DA/DB	Biostimulation / bioaugmentation through biobarriers (dissolved plume)	With proper microbe culture this is an effective way to reduce the contaminant mass.	Technology feasible	Moderate to high in cost	Retain
11	SA/SB	Biostimulation / bioaugmentation of the source area (DNAPL area)	With proper microbe culture this is an effective way to reduce the contaminant mass.	Technology feasible	Moderate in cost	Retain

Note:
* Shading indicates alternatives eliminated after screening

Acronyms/Abbreviations:
DNAPL – dense nonaqueous-phase liquid
IR – Installation Restoration (Program)
MNA – monitored natural attenuation
NCP – National Oil and Hazardous Substances Pollution Contingency Plan
RAO – remedial action objective

Section R-5
DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES

This section details the revised remedial alternative for IR Site 70 and evaluates it against regulatory criteria. Alternative 11 was developed based on screening results (Section R-4). Section R-5.1 summarizes the criteria for assessing remedial alternatives, as specified in the NCP. Section R-5.3 describes Alternative 11 for IR Site 70, emphasizing how the technology and process options would be applied. Section R-5.3 also evaluates how Alternative 11 meets the NCP criteria.

R-5.1 REVIEW OF CRITERIA USED FOR DETAILED ANALYSIS OF POTENTIAL REMEDIAL ACTION ALTERNATIVES

The following nine criteria are stipulated in the NCP at 40 CFR 300.430(e)(9)(iii) for the evaluation of remedial alternatives under CERCLA:

- overall protection of human health and the environment;
- compliance with ARARs;
- long-term effectiveness and permanence;
- reduction of toxicity, mobility, or volume through treatment;
- short-term effectiveness;
- implementability;
- cost;
- state acceptance; and
- community acceptance.

The NCP divides these criteria into three groups: threshold, primary balancing, and modifying criteria. *Threshold criteria* include overall protection of human health and the environment and compliance with ARARs. *Primary balancing criteria* include long-term effectiveness and permanence; reduction of toxicity, mobility, or volume through treatment; short-term effectiveness; implementability; and cost. *Modifying criteria* include state and community acceptance.

The nine NCP criteria are further defined by subcriteria and other factors (U.S. EPA 1988). The following subsections explain the nine NCP criteria and summarize relevant subcriteria and other factors.

R-5.1.1 Overall Protection of Human Health and the Environment

This criterion assesses the extent to which an alternative protects human health and the environment considering site characteristics and expected risk reduction. Evaluation of the overall protection of human health and the environment afforded by each alternative draws on assessments made under several other NCP criteria, especially short-term effectiveness, long-term effectiveness and permanence, and compliance with ARARs.

The following issues are addressed for each alternative under this criterion:

- reduction in risk to human health and the environment; and
- ability to achieve remediation goals for IR Site 70 groundwater.

R-5.1.2 Compliance With ARARs

This criterion assesses whether an alternative would comply with all applicable or relevant and appropriate federal and state ARARs, as defined by CERCLA Section 121 and identified in Appendix R-B. When an ARAR is not met, the basis for justifying one of the six waivers allowed under CERCLA should be discussed.

R-5.1.3 Long-Term Effectiveness and Permanence

This criterion examines the impact of a remedial alternative in the long term, defined in U.S. EPA guidance as the time after RAOs are met (U.S. EPA 1988). Thus risk to human and environmental receptors from remaining COC-impacted groundwater, is considered at the completion of remedial activities. Evaluation of a remedial alternative relative to its long-term effectiveness and permanence is made considering the following four factors:

- magnitude of the residual risk to human and environmental receptors from remaining COC-impacted groundwater contaminants at the completion of remedial activities. This includes impacts to the aquifer due to the remedial approach, such as increased salt water intrusion or byproducts from the remedy;
- type, degree, and adequacy of long-term management (including engineering controls, monitoring, and O&M) required for COC-impacted groundwater contaminants remaining at the site;
- long-term reliability of engineering and/or institutional controls to provide continued protection from COC-impacted groundwater contaminants; and
- the potential need to replace components of the remedy and the continuing need for repairs or maintenance.

R-5.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

According to CERCLA, preferred cleanup alternatives use technologies that permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances (compared to baseline levels [no action alternative]). For IR Site 70, this would mean using technologies that:

- destroy VOCs in groundwater;
- reduce the total mass of VOCs in the subsurface;
- reduce the volume of VOC-impacted groundwater; or
- irreversibly reduce VOC mobility.

(Alternatives that do not use treatment technologies to achieve these goals, such as excavation and off-site landfill disposal of COC-affected groundwater, do not reduce the toxicity, mobility, or volume of contaminants.) The agencies also evaluate the reduction of toxicity, mobility, and volume with respect to remedial by-products that may impact groundwater.

Evaluation of alternatives for reduction of toxicity, mobility, or volume considers:

- treatment processes used;
- amount of hazardous materials to be treated, including how the principal threats at the sites would be addressed;
- degree of expected reduction in toxicity, mobility, or volume measured as a percentage of baseline levels;
- degree to which the treatment is irreversible; and
- type and quantity of treatment residuals.

R-5.1.5 Short-Term Effectiveness

This criterion considers how an alternative affects human health and the environment during cleanup (i.e., the short term). "Short term" is defined as the time required to plan, design, construct, and operate a system of cleanup until RAOs are achieved (U.S. EPA 1988). Four factors are considered:

- short-term risks that might be imposed on the community, such as dust from excavation of header trenches for groundwater extraction equipment;
- potential impacts to workers during construction and O&M, as well as the effectiveness and reliability of the protective measures that would be taken;
- potential environmental impacts of the remedial action and the effectiveness and reliability of mitigation measures that would be taken during implementation; and
- amount of time required before RAOs are achieved (i.e., the duration of the short term).

R-5.1.6 Implementability

This criterion evaluates the technical and administrative feasibility of an alternative. The availability of required equipment, materials, and services is also considered. When assessing implementability, the following factors are considered.

- Technical feasibility, which refers to the relative ease of implementing or completing an action based on site-specific constraints, including the use of established technologies. Considered are:
  - constructability of components necessary for the alternative;

  - operational reliability, or the likelihood that a technology would meet specified efficiency levels or performance goals;
  - ability of the owner to undertake future remedial actions that may be required and difficulty of implementing such actions; and
  - ability of the owner to monitor the effectiveness of the remedy.
- Administrative feasibility, including the ability (as well as time) required to obtain approvals from governmental bodies.
- Availability of services and materials required to implement the alternative, including:
  - capacity and location of off-site treatment, storage, and disposal services;
  - equipment (such as heavy construction equipment) and specialists;
  - time needed to develop new or innovative technologies under consideration, including the time required for bench tests and pilot tests; and
  - potential for competitive construction bids, a factor that may be particularly important for innovative technologies such as *in situ* chemical oxidation.

R-5.1.7 Cost

For each remedial alternative, a cost estimate has been developed based on investigation data from the ERSE (BNI 1999a) and Technical Memorandum 5 (BNI 1999c). Procedures outlined in U.S. EPA guidance (U.S. EPA 1987) were followed in developing the cost estimates for each alternative, which are based on the conceptual engineering designs presented in this section. The cost data for the original FS alternatives have been escalated at a 3 percent rate per year to bring them to 2005 dollars. The assumptions and cost elements for the existing alternatives remain the same unless noted in Appendix R-D. The cost estimate for Alternative 11 includes capital costs and O&M costs and are expressed as net present value in terms of January 2005 dollars (Appendix R-D).

R-5.1.8 State Acceptance

This criterion evaluates the remedial alternatives with respect to the concerns of State agencies. The State of California will review and comment on this RFS Report; State responses will be considered when revising this report. State comments will also be considered in finalizing the ROD and proposed plan. The criterion of State acceptance is briefly assessed in Section R-6.

R-5.1.9 Community Acceptance

This criterion assesses issues of concern to the community regarding each remedial alternative. Comments will be solicited from community members during the public review period for this RFS. These comments will be considered in the remedy selection process. A summary of public comments and responses will be included in the ROD.

Although community acceptance will be evaluated after the public comment period for the Proposed Plan, this criterion is briefly assessed in Section R-6.

5.2 DESCRIPTIONS AND DETAILED ANALYSES OF REMEDIAL ALTERNATIVES FOR IR SITE 40

5.2.1 Alternative 1 – No Action

5.2.1.1 DESCRIPTION OF ALTERNATIVE

5.2.1.2 EVALUATION BY CRITERIA

5.2.2 Alternative 2 – MNA

5.2.2.1 DESCRIPTION OF ALTERNATIVE

5.2.2.2 EVALUATION BY CRITERIA

5.2.3 Alternative 3 – Hydraulic Containment

5.2.3.1 DESCRIPTION OF ALTERNATIVE

5.2.3.2 EVALUATION BY CRITERIA

5.2.4 Alternative 4 – Pump and Treat

5.2.4.1 DESCRIPTION OF ALTERNATIVE

5.2.4.2 EVALUATION BY CRITERIA

5.2.5 Alternative 5 – *In Situ* Treatment

5.2.5.1 DESCRIPTION OF ALTERNATIVE

5.2.5.2 EVALUATION BY CRITERIA

R-5.3 DESCRIPTION AND DETAILED ANALYSIS OF REMEDIAL ALTERNATIVES FOR IR SITE 70

The existing FS evaluated five alternatives for addressing the dissolved-phase plume and suspected DNAPL area at IR Site 70. These included:

- Alternative 1, no action;
- Alternative 6, hydraulic containment (dissolved plume) and *in situ* chemical oxidation treatment (DNAPL area);

- Alternative 7, hydraulic containment (dissolved plume) and pump and treat (DNAPL area);
- Alternative 9, pump and treat (dissolved plume) and *in situ* chemical oxidation treatment (DNAPL area); and
- Alternative 10, pump and treat (dissolved plume) and pump and treat (DNAPL area).

The RFS evaluates the use of enhanced bioremediation through biostimulation of intrinsic organisms or bioaugmentation with a stable halorespiring culture. Enhanced bioremediation will address the dissolved phase plume through the use of biobarriers that intercept and treat the contaminant plume. The inferred DNAPL area and corresponding dissolved phase plume will be treated through a grid of injection wells that cover the shallow contaminant plume. Alternative 11 will include MNA, groundwater monitoring as a support technology, and institutional controls to prevent humans from being exposed to contaminated groundwater. The conversion to MNA should be seamless since the enhanced bioremediation approach is directly compatible with subsequent MNA. The RFS will document Alternative 11.

- Alternative 11, biostimulation and bioaugmentation through construction of biobarriers to treat the dissolved plume, and biostimulation and bioaugmentation to treat the DNAPL area.

5.3.1 Alternative 1 – No Action

5.3.2 Alternative 6 – Hydraulic Containment (Dissolved Plume) and *In Situ* Treatment (DNAPL Area)

5.3.2.1 DESCRIPTION OF ALTERNATIVE

5.3.2.2 EVALUATION BY CRITERIA

5.3.3 Alternative 7 – Hydraulic Containment (Dissolved Plume) and Pump and Treat (DNAPL Area)

5.3.3.1 DESCRIPTION OF ALTERNATIVE

5.3.3.2 EVALUATION BY CRITERIA

5.3.4 Alternative 9 – Pump and Treat (Dissolved Plume) and *In Situ* Treatment (DNAPL Area)

5.3.4.1 DESCRIPTION OF ALTERNATIVE

5.3.4.2 EVALUATION BY CRITERIA

5.3.5 Alternative 10 – Pump and Treat (Dissolved Plume) and Pump and Treat (DNAPL Area)

5.3.5.1 DESCRIPTION OF ALTERNATIVE

5.3.5.2 EVALUATION BY CRITERIA

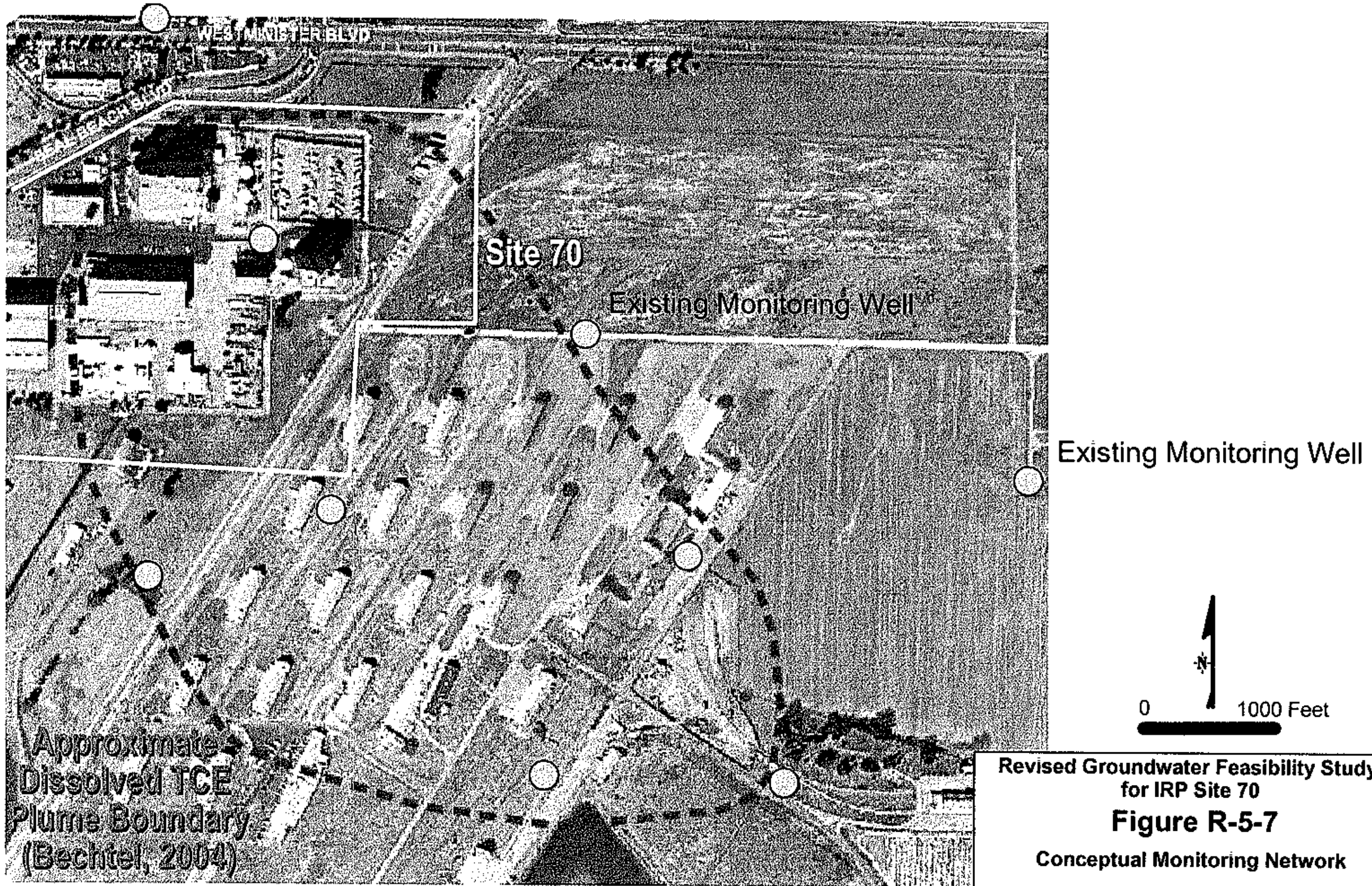
R-5.3.6 Alternative 11 – Enhanced Bioremediation

R-5.3.6.1 DESCRIPTION OF ALTERNATIVE

Under Alternative 11, enhanced bioremediation would reduce contaminant levels in the plume by creating biobarriers that intercept and treat the dissolved phase plume and treat the source through enhancing the mass removal rate of DNAPLs. A long-term monitoring program, including periodic reviews, would track plume migration and cleanup progress. A conceptual monitoring well layout is shown in Figure R-5-7. Institutional controls would restrict use of parcels overlying the plume so that humans would not be exposed to contamination. Institutional controls would also preclude taking actions that would interfere with enhanced bioremediation. To reduce uncertainty and time to achieve measurable results, bioaugmentation would be implemented as soon as the addition of electron donor stimulated the indigenous microorganisms to create the appropriate geochemical conditions under which *Dehalococcoides* in the KB-1™ culture are known to grow. Injection of the KB-1™ culture will be through the same wells used for injection of the electron donor.

The following assumptions pertain to application of this Alternative:

- Bioremediation in the subsurface at IR Site 70 will reduce contaminant dissolved phase concentrations and meet RAOs;
- Bioremediation will enhance the dissolution rate of free-phase DNAPL;
- Biodegradation rates will be sufficiently fast to meet remedial action objectives at the downgradient edge of the source areas and biobarriers;
- Contaminant migration in the upper and lower sand is predominantly horizontal;
- Reduction of the contamination in the shallow aquifer would reduce the threat to the deeper aquifer;
- The existing data from previous investigations accurately reflects the site groundwater and soil conditions, such as permeability, composition, hydraulic conductivity, vertical and horizontal groundwater gradients, and velocities; and
- Groundwater monitoring will adequately determine the effectiveness of the biobarrier and source treatment systems.



Revised Groundwater Feasibility Study for IRP Site 70

Figure R-5-7

Conceptual Monitoring Network

Naval Weapons Station, Seal Beach, California

GeoSyntec Consultants

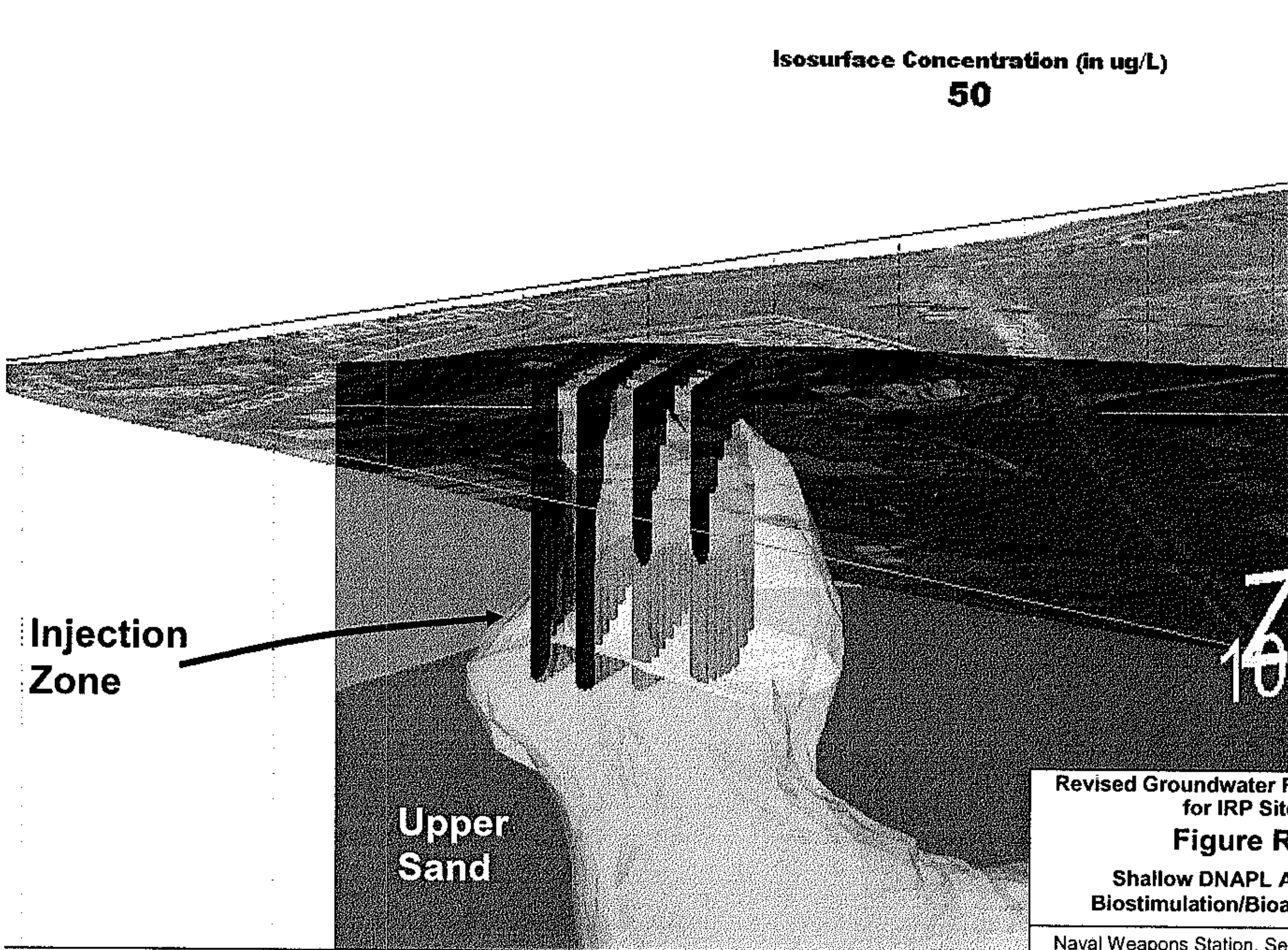
Date: 11/23/04
File No: 127R4593
Job No: HY0888
Rev No: A

Alternative 11 treatment components are based on the existing data from previous investigations. The spacing of injection well points and biobarrier treatment zones are based on data from the RI (BNI, 1999). Treatability tests will determine the final treatment elements including the rate of natural attenuation, the achievable distribution of electron donor and required well spacing, and other elements to the enhanced bioremediation approach. The projected effectiveness of Alternative 11 is based on results observed at IR Site 40, other Southern California sites, and test projects at other federal facilities.

Demonstrations of the enhanced bioremediation of chlorinated DNAPL and dissolved phase plumes have been completed under the U. S. EPA Superfund Innovative Technology Evaluation program. Test results from Launch Complex 34 (LC 34) at Cape Canaveral indicate TCE mass removal in excess of 98.5 percent. SITE results are documented in *Demonstration of Biodegradation of DNAPL Through Bioaugmentation at Launch Complex 34 in Cape Canaveral Air Force Station, Florida* (EPA, 2004). A summary of these results indicate that TCE concentrations in excess of 8,000 mg/kg were reduced to less than 10 mg/kg over a 12 month period. The bioaugmentation results from the LC 34 study indicate that TCE, cis-DCE, and VC are converted to ethene within 3 to 4 months.

The enhanced treatment approach for the DNAPL area will consist of a grid of injection wells that cover the source area (Figure R-5-12). These wells will be constructed so that injections can be made at future dates as needed. Bioaugmentation and subsequent monitoring is the same as for the biobarriers. Monitoring data will be used to determine the need for additional electron donor injections, growth and dispersion of *Dehalococcoides,* and groundwater quality. The start up monitoring program will be at a more frequent rate to identify the dechlorination rate and to demonstrate the complete dechlorination to ethenes within the target timeframe.

Based on existing data, the conceptual approach to implement the biobarriers within the dissolved plume include the use of multiple well points that will transect the plume at selected locations. Figure R-5-13 provides a conceptual model of the biobarriers within the upper sand. FigureR-5-14 provides a conceptual model of the distribution of biobarriers within the lower sand. A plan view of the system layout is provided in Figure R-5-15. These transects will consist of individual well points that will allow multiple dosing of EVO on an as needed basis. Final spacing of the well points will be determined based on design investigation results. Addition of the EVO will create a reduced environment conducive to microbial growth. Once the appropriate geochemical conditions that support the growth and activity of *Dehalococcoides* are established, the biobarriers will be inoculated with KB-1™. Dispersion of the KB-1™ will be monitored along with electron donor and contaminant concentrations (see Table R-5-19).



Revised Groundwater Feasibility Study for IRP Site 70

Figure R-5-12

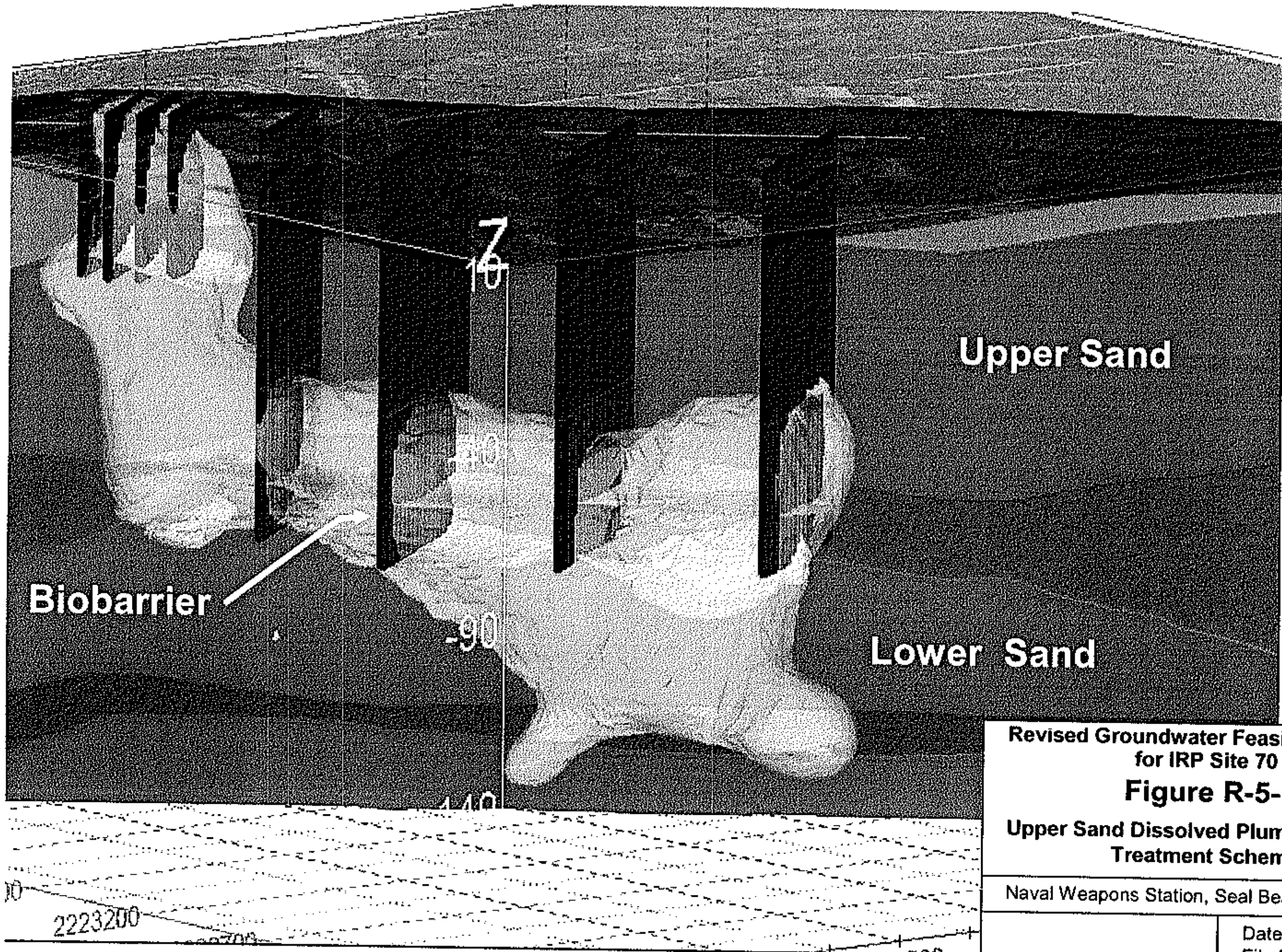
Shallow DNAPL Area In-Situ Biostimulation/Bioaugmentation

Naval Weapons Station, Seal Beach, California

GeoSyntec Consultants

Date: 11/23/04
File No: 127R4593
Job No: HY0888
Rev No: A

Isosurface Concentration (in ug/L) 50



Revised Groundwater Feasibility Study for IRP Site 70

Figure R-5-13

Upper Sand Dissolved Plume Biobarrier Treatment Scheme

Naval Weapons Station, Seal Beach, California

GeoSyntec Consultants

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Job No: HY0888
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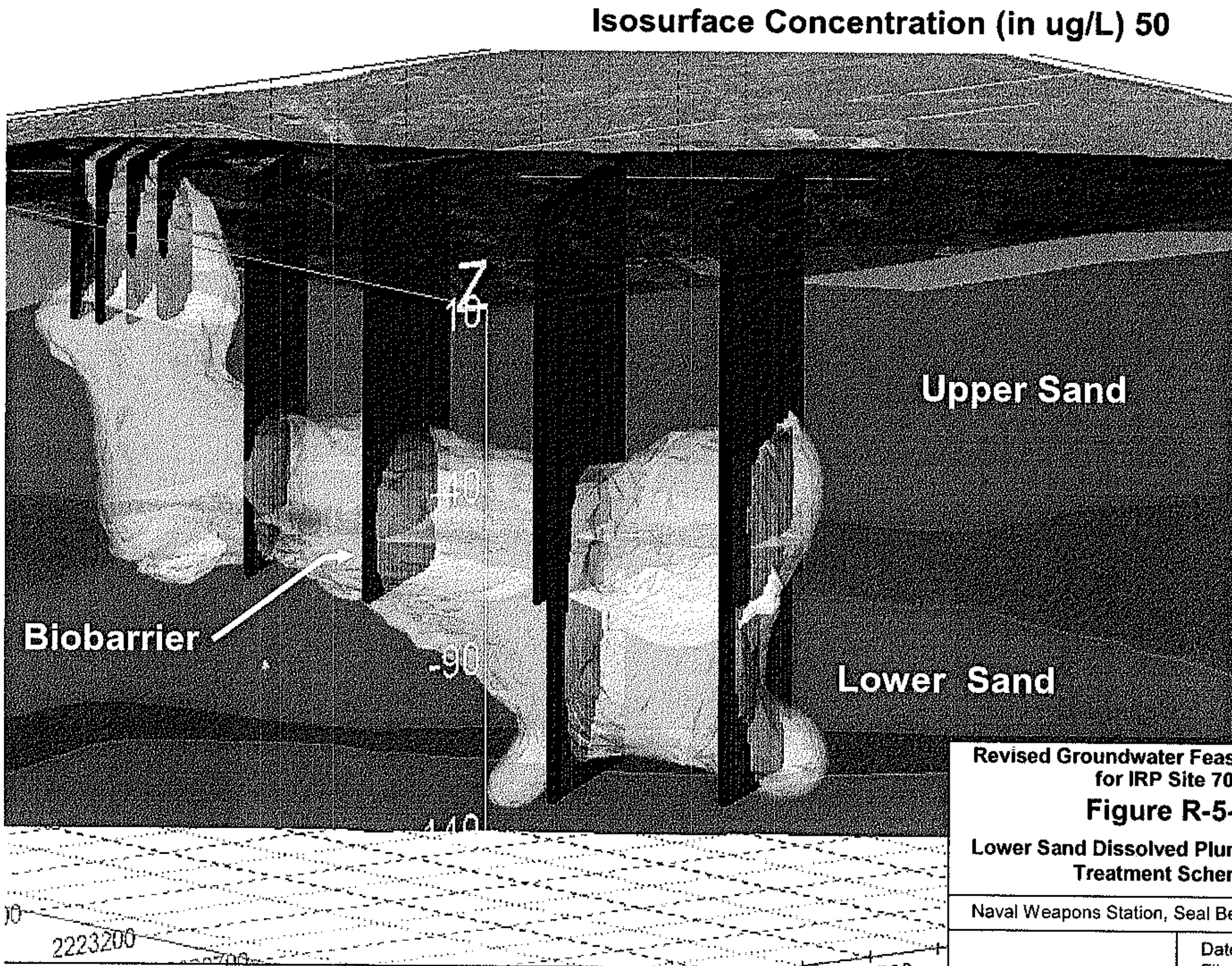


Revised Groundwater Feasibility Study for IRP Site 70

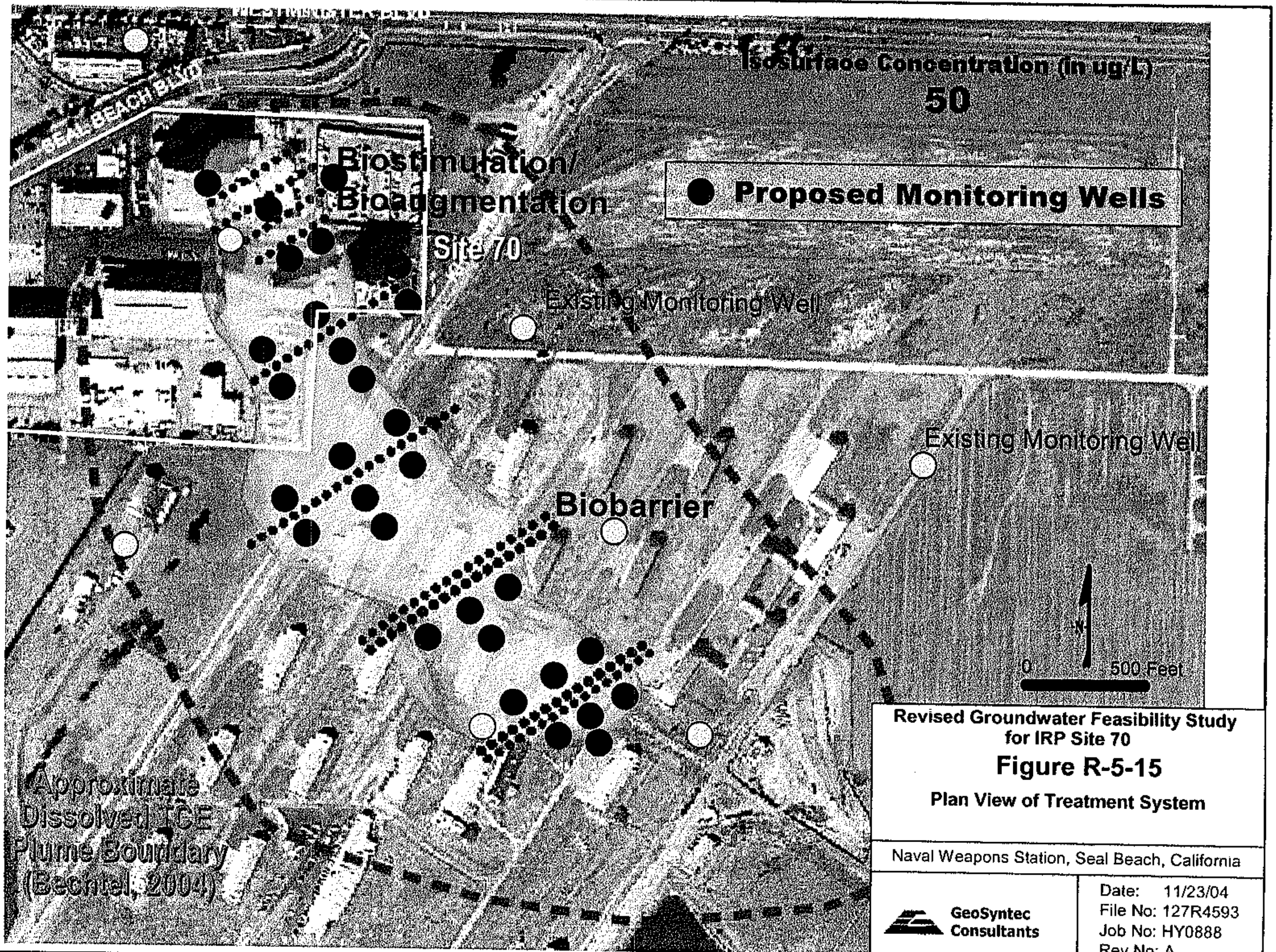
Figure R-5-14

Lower Sand Dissolved Plume Biobarrier Treatment Scheme

Naval Weapons Station, Seal Beach, California

GeoSyntec Consultants

Date: 11/23/04
File No: 127R4593
Job No: HY0888
Rev No: A



Revised Groundwater Feasibility Study for IRP Site 70

Figure R-5-15

Plan View of Treatment System

Naval Weapons Station, Seal Beach, California

GeoSyntec Consultants

Date: 11/23/04
File No: 127R4593
Job No: HY0888
Rev No: A

Table R-5-19
In Situ Treatment Verification Requirements for Alternative 11
IR Site 70

Type of Monitoring Data	Monitoring Locations	Purpose/Use of Data
Water levels	Monitoring wells throughout and around the IR Site 70 DNAPL area and upgradient and down gradient of the biobarriers	Prepare potentiometric surface maps and hydrographs. Determine horizontal and vertical hydraulic gradients, and extent of seasonal variations.
VOC concentrations in the aquifer	Monitoring wells throughout and around the IR Site 70 DNAPL area and dissolved plume biobarriers	Monitor contaminant distribution. Confirm remediation of plume and assess progress toward cleanup goals. Estimate remaining contaminant mass Detect microorganism distribution
Aquifer parameters, including pH, temperature, conductivity, ORP, dissolved oxygen and gases	Monitoring wells throughout and around the IR Site 70 DNAPL area and dissolved phase plume	Support data for assessment of process efficiency and effect of treatment on the aquifer.
Electron donor distribution (EVO)	Monitoring wells throughout and around the IR Site 70 DNAPL area and biobarriers	Assure that sufficient electron donor concentrations remain to maintain microbial action.
Water quality parameters, including TDS, cations, anions, alkalinity, metals	Monitoring wells throughout and around the IR Site 70 DNAPL area and biobarriers	Monitor buffering capacity of the aquifer, effect of treatment on aquifer chemistry.

Acronyms/Abbreviations:
DNAPL – dense nonaqueous-phase liquid
IR – Installation Restoration (Program)
VOC – volatile organic compound
ORP – oxidation reduction potential
TDS – total dissolved solids

Groundwater monitoring will be conducted to evaluate the effectiveness of each step of the enhanced bioremediation. To accomplish this, monitoring wells will be constructed and subsequently sampled within the biobarrier treatment zone and immediately up and downgradient of the biobarriers. These sample data will be used to verify the effectiveness of the enhanced bioremediation approach.

Microcosm studies, which will be completed in the remedial design investigation, will provide data on the removal efficiency under enhanced bioremediation and natural attenuation conditions. Modeling results are provided in Appendix R-E. These results are based on the observations from demonstrations and field tests. The modeling results indicate significant mass removal from the plume within the biobarrier. In addition, natural attenuation processes will occur downgradient and between the biobarriers further reducing the COC to meet RAOs. As described in Appendix R-E, there are uncertainties in the modeling analysis, particularly in the estimate of natural attenuation rates, and the results should be interpreted based on the comparative effectiveness among the alternatives rather than on the absolute cleanup timeframes, which could vary significantly.

Biannual monitoring would involve collecting and analyzing groundwater samples from wells within and along the downgradient migration pathways of the plume (Appendix R-C). Six existing monitoring wells would be utilized, and an additional five monitoring wells would be installed initially (Table R-5-20, Figure R-5-15). Additional monitoring wells will be added based on the number of biobarriers installed. Groundwater levels would be measured in new and existing wells to confirm groundwater flow patterns and vertical gradients. Monitoring will be performed to track the plume over time and identify that dechlorination is occurring at rates sufficient to attain RAOs and within the timeframe predicted by groundwater modeling (Appendix R-E2). A long-term remediation monitoring plan (RMP) would document the actual monitoring program and contain a contingency plan triggering actions to manage any future expansion of the plume per U.S. EPA guidance (U.S. EPA 1998, 1999). Additional well installation to track changes in the extent of the plume are included as part of this alternative (Appendix R-D). The cost of additional wells is incorporated into the long-term monitoring costs.

Monitoring data would be used for periodic reviews every year to assess plume migration, dechlorination activity, to evaluate the extent of microbial migration, and the adequacy of the remedial action to meet RAOs. Reviews would be documented in a summary report issued to appropriate regulatory agencies. These reports may suggest modifications to the cleanup program as needed.

Institutional Controls

In addition to preventing exposure under future land uses, the institutional controls would protect existing monitoring wells and grant access for sampling, installing new monitoring wells, and implementing any additional remedial measures needed in the future. Because off-base migration is not likely, institutional controls on off-base property would not be necessary.

It is assumed that the DON would retain administrative control of the site and the institutional controls would be in effect until monitoring data shows contamination levels below remediation goals.

Table R-5-20
Proposed Performance Monitoring Requirements for Alternative 11
IR Site 70

Type of Monitoring Data	Monitoring Locations	Purpose/Use of Data
Water levels	Monitoring wells along downgradient perimeters, within the plume, down gradient of biobarriers, within biobarriers and DNAPL area and in upgradient areas	Prepare potentiometric surface maps. Determine horizontal and vertical hydraulic gradients. Identify potential barriers to flow. Quantify impact of seasonal variations.
Field parameters	Monitoring wells throughout and around the IR Site 70 vicinity plume	Confirm dechlorination and anaerobic conditions.
Volatile fatty acids (lactate, propionate, formate, butyrate, hexanoate)	Monitoring wells throughout and around the IR Site 70 vicinity plume	Confirm continuing presence of oil.
Dissolved metals (iron, manganese, arsenic, etc.)	Select monitoring wells throughout and around the IR Site 70 vicinity plume	Monitor secondary groundwater impacts to groundwater quality.
Anions (sulfate, chloride, nitrate, phosphate, sulfide, nitrite)	Monitoring wells throughout and around the IR Site 70 vicinity plume	Monitor for presence of competing electron acceptors and to confirm dechlorination activity (chloride production)
Dissolved Hydrocarbon Gases (methane, ethane, ethene)	Monitoring wells throughout and around the IR Site 70 vicinity plume	Confirm dechlorination sequence to non-toxic end products and gather data to define mass balance for remedial zones.
Biochemical oxygen demand (BOD) and total organic carbon (TOC)	Monitoring wells throughout and around the IR Site 70 vicinity plume	Confirm continuing presence of oil.
DHE PCR	Select monitoring wells throughout and around the IR Site 70 vicinity plume	Monitor bioremediation culture distribution and continuing viability.
VOC concentrations in the aquifer	Monitoring wells throughout and around the IR Site 70 vicinity plume	Confirm dechlorination sequence, gather data to define mass balance for remedial zones
VOC concentrations in extracted groundwater	Extraction wells for mixing with EVO and bioaugmentation culture.	Monitor concentrations within treatment zones. Provide water quality data for water discharge requirements (WDR) monitoring requirements.
VOC concentrations in reinjected water-EVO mixture	Effluent lines from mixing unit at each treatment area (source area and biobarrier)	Demonstrate substantive compliance with the WDR.
Flow rates	Extraction wells and injection wells	Confirm that extraction and reinjection rates are compatible, identify potential biofouling issues
Other operational parameters (e.g., waterline pressures)	Various locations	As needed to assess proper operation or incipient failure of pumps and filters.

Acronyms/Abbreviations:
IR – Installation Restoration (Program)
EVO – Emulsified Vegetable Oil
WDR – Waste Discharge Requirements
VOC – Volatile Organic Compound

R-5.3.6.2 EVALUATION BY CRITERIA

Evaluation of Alternative 11 by threshold and balancing criteria follows.

Overall Protection of Human Health and the Environment

Alternative 11 is considered protective of human health and the environment. This alternative is expected to achieve remediation goals. The time to achieve those goals will be related to the microbial degradation rate that is achieved within the source and dissolved phase plumes. The target remediation time is 15 years to reach RAOs. MNA rates will be monitored after the enhanced bioremediation is discontinued. In the interim, institutional controls would prevent exposure to contaminated groundwater. Long-term groundwater monitoring and periodic reviews would track potential plume migration, microbial distribution, dechlorination rates, and provide information to support any future remedial actions needed.

The DON's current administrative controls prevent exposure to the contaminated groundwater, which is considered unsuitable for consumption. In the event of future changes in ownership, institutional controls would prevent exposures.

Compliance with ARARs

Alternative 11 is expected to meet chemical-specific, location-specific, and action-specific ARARs. The remedial action will monitor the establishment of the halorespiring microorganisms throughout the treatment areas. The timeframe required to attain the RAOs will be evaluated, and treatment modifications will be initiated if they are needed to meet the cleanup schedule. In the interim, institutional controls would prevent inadvertent exposure to contaminated groundwater.

Soil cuttings and well development water generated during the installation of monitoring wells for Alternative 11 would be subject to RCRA requirements to determine whether such wastes should be classified as hazardous. This determination would be made at the time the waste is generated. The appropriate management requirements for storing, manifesting, and transporting this material for final disposal would be followed if the soil cuttings or well development water are found to be RCRA or non-RCRA hazardous waste.

Long-Term Effectiveness and Permanence

Alternative 11 provides long-term effectiveness and permanence compared to the other alternatives. The microbial dechlorination is effective against sorbed and free-phase COCs. This alternative will result in the removal of residual and dissolved-phase constituents, and any remaining residuals will be further removed through MNA processes. Furthermore, until MNA finishes the removal of residual contaminants in groundwater, administrative controls such as institutional controls, will be used to prevent exposure to groundwater that is above RAO. Institutional controls would prevent future human exposures. The long-term effectiveness of these measures would depend on their continued enforcement.

Institutional controls have been routinely implemented at hazardous waste release sites in the United States. These activities are expected to be reliable in minimizing future health risks associated with the contaminated plume.

The passive nature of Alternative 11 provides this alternative with adequate and reliable controls over long timeframes without replacing the technical components of the remedy. The *in situ* destruction of the contaminants prevents the need to dispose of and manage residuals, and the MNA remedy will continue to actively remove or contain contaminants. Parsons (1998) has shown that natural biodegradation processes are actively affecting the plume as modeled site data indicates that the plume is shrinking, stable, or growing at a rate slower than predicted solely on advective transport of the COCs.

A possible limitation on the long-term effectiveness of Alternative 11, although very unlikely, is the potential need for future remedial actions resulting from plume migration. It is unlikely that the plume would migrate off base. However, monitoring and periodic reviews would be used to evaluate potential off-base migration, along with any needed additional remedial action.

Reduction of Toxicity, Mobility, or Volume through Treatment

Alternative 11 would reduce the volume, mobility, and toxicity of VOCs through microbial dechlorination to non-toxic end-products. Production of more toxic intermediates will be extremely short relative to the entire duration of the remedy and will be substantially reduced by bioaugmentation to rapidly establish the population density of *Dehalococcoides* required to ensure the rapid conversion of these intermediates to non-toxic ethene. The enhanced bioremediation is expected to destroy the DNAPL and dissolved phase components of the plume. In addition, as the VOCs are dechlorinated to ethenes, the toxicity is significantly reduced. The mobility of the end products may not be significantly altered under this approach; however, the dechlorination process and rates will contain and reduce the apparent mobility of the parent and degradation products. Possible secondary water quality impacts could be observed, such as increases in dissolved metals (such as iron), biological oxygen demand, and methane. However, these parameters will be removed downgradient from the biological active zones due to natural processes.

Short-Term Effectiveness

The short-term impacts will be minimal because the remedy is *in situ* and passive. The major short term impact will be the drilling and injection phase of the project. During drilling, potential exposure to contaminated drilling mud, soils, and groundwater will be likely. Mitigation measures will be developed within the site Work Plan and Health and Safety Plan. Contaminated materials from the drilling phase will be segregated and disposed of through appropriate methods. On-site construction activities for Alternative 11 would be limited to the installation of groundwater injection and monitoring wells and possible temporary piping layouts between the well heads and the mixing units. The initial on-site well drilling and development activities would take approximately 6 months. To minimize risks to workers and the community, a site-specific health and safety plan and remedial action work plan would be implemented. These plans would provide for personnel protection, soil and drilling mud containment, and air monitoring. If required, off-site disposal of contaminated drilling materials will be implemented.

The remedial evaluation monitoring plan will be incorporated within the Remedial Design submittal. The groundwater monitoring program at the site will include plans for handling and disposing of contaminated groundwater (possibly through reinjection into the biobarriers). By following the proposed site specific health and safety plan and work plan, the potential for human or ecological exposure should continue to be negligible.

Workers could be exposed to various amendments such as EVO, inorganic nutrients (e.g., salts of nitrate, ammonia, phosphate), and KB-1™ amendments. EVO is composed of food-grade compounds, KB-1™ is certified pathogen-free, and the microorganisms are suspended in a mineral salts media. None of the amendments are inherently hazardous, but standard protective measures will be used to prevent exposure (skin, eyes, ingestion, and inhalation). During the implementation of this alternative, there is the potential for exposure to site groundwater. Groundwater from the intermediate zone will be pumped to provide the site water for mixing and injection of amendments. This extraction, injection, and mixing will be conducted with appropriate apparatus that will reduce or eliminate the handling or exposure to groundwater and amendments. All of the tanks, piping, pumps, and valves, and amendments will be within a containment area to provide protection from spills, leaks, and component failure.

The time to achieve cleanup goals is estimated to be reasonable (substantially within a typical 15-year project life), with the majority of the plume mass degraded within 8 years (Appendix R-E) for the conceptual design shown in Figures R-5-12, R-5-13, and R-5-14. Source removal is estimated to occur within 15 years (actual clean up time of the source will depend on DNAPL mass present and its distribution as pools or residuals). A larger biobarrier spacing may result in a lower remedial cost but longer remediation times. Preliminary cost optimization of the biobarrier spacing indicates that a lower cost may be achieved by using biobarriers placed only at the plume toe (NPV cost changes from $14,663,000 to $12,914,000); however, plume remediation duration increases from up to 8 years to up to 18 years (Appendix R-E). Treatment cost and duration is also sensitive to the rate of natural attenuation within the plume, with a factor of two increase in the natural attenuation half-life resulting in a 12% increase in costs and increased duration from up to 8 years to up to 18 years (Appendix R-E). Optimization of the remedial design will be performed during the design phase after natural attenuation rates are better characterized to balance treatment duration and costs; therefore, actual remedial time may be greater or less than the preliminary 8 and 15 years estimates.

Implementability

Alternative 11 is readily implemented by using conventional and commercially available materials and construction techniques. Drilling methods such as hollow-stem auger and mud rotary have been proven at the site. Standard monitoring wells are applicable for performance assessment of the alternative. The equipment and materials for the injection process are proven, reliable, and straightforward in their operation. Installation will require clearance and work in areas where structures, utilities, and access issues exist. The monitoring and injection wells would be located for ceasy access and minimal impact on future land uses and adjacent industrial properties, but within the constraints required to meet the monitoring and performance requirements of the remedy. Utility clearance will be conducted prior to drilling.

The DON would continue to control land use. If ownership changes, this alternative would necessitate coordination with state and local agencies to administer institutional controls. However, administrative complications would be unlikely.

Cost

The net present value for Alternative 11 would be approximately **$14,663,000** (Table R-5-21). This estimate is solely for comparing alternatives in this RFS; it should not be used for budgetary or planning purposes.

The major components of this cost estimate include the remedial investigation design, drilling and well construction, monitoring wells, analytical, microbial culture, and electron donor costs. The labor to complete this task and to provide 15 years of operation and maintenance, monitoring, and evaluation are defined in more detail in Appendix R-D. Recurring costs such as groundwater monitoring and electron donor are similar for similar type of remedial approaches.

Table R-5-21
Cost Estimate Summary – IR Site 70
Alternative 11 – Bioaugmented Biobarriers (Dissolved Plume) and Biostimulation with Bioaugmentation (DNAPL Area)

Description	Cost
Capital Costs	
Groundwater monitoring wells (installation of 42 wells)	$166,000
Oil amendment injection wells (installation of 212 wells)	$1,097,000
Temporary oil injection equipment	$100,000
Professional labor (includes Proposed Plan, Record of Decision, Remedial Action Plan, workplan, design and startup, well installation oversight)	$2,162,000
Site characterization and laboratory treatability study	$800,000
Total capital costs (based on January 2005 dollars, including profit and overhead)	**$4,325,000**
O&M Costs	
Oil emulsion (15 year supply)	$4,199,000
Oil injection labor (15 years)	$574,000
Monitoring (includes 20% QA/QC, sampling, analysis, mobilization and labor)	$2,003,000
Gene-Trac analysis	$108,000
KB-1™	$602,000
Annual Professional Costs (five year reviews, annual reporting, field program start-up and management)	3,865,000
Total O&M Costs (including 2.5% inflation per annum)	**$11,351,000**
Subtotal	**$15,676,000**
Total (including 20% contingency)	**$18,810,000**
NET PRESENT VALUE (based on January 2005 dollars)	**$14,663,000**

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Section R-6
COMPARATIVE ANALYSIS OF REMEDIAL ALTERNATIVES

The RFS compares Alternative 11 with the alternatives from the original FS. With the addition of the new alternative evaluated in the revised Section 5, the current 6 alternatives under review provide a wide range of options for remediation of the VOC-contaminated groundwater associated with IR Site 70. As discussed in Section R-4.1, these alternatives were developed after consideration of the requirements of the NCP and U.S. EPA technical guidance (U.S. EPA 1988), the statutory preferences listed in CERCLA Section 121(b), and RAOs (Section R-2).

This section compares the relative performance of the remedial alternatives considered in this RFS and the original FS against the NCP evaluation criteria (Section R-5.1). This comparative analysis distinguishes the advantages and disadvantages of each alternative and identifies key trade-offs the DON must consider when selecting a cleanup remedy. When selecting a final remedy under CERCLA, the NCP criteria are evaluated according to the following hierarchy per 40 CFR 300.430(f):

- Threshold criteria:
  - Overall protection of human health and the environment
  - Compliance with ARARs
- Primary balancing criteria:
  - Long-term effectiveness and permanence
  - Reduction of toxicity, mobility, or volume through treatment
  - Short-term effectiveness
  - Implementability
  - Cost- effectiveness
- Modifying criteria:
  - State acceptance
  - Community acceptance

CERCLA Section 121(d) and the NCP at 40 CFR 300.430(f)(1)(ii) require that a cleanup remedy must protect human health and the environment and comply with ARARs, unless justification to waive a specific ARAR is provided in the ROD. In other words, both threshold criteria must be satisfied for a remedial alternative to be eligible for selection, unless an ARARs waiver applies.

Therefore, the trade-offs among eligible alternatives will generally be in the areas addressed by the five primary balancing criteria and the two modifying criteria. The following subsections address the primary balancing criteria only. To facilitate the discussion, these five criteria are evaluated and compared in the same order as in the detailed analysis of alternatives for IR Site 70 presented in Sections 5.2 through 5.3, respectively. As noted in Section 5, the two modifying criteria (state acceptance and community acceptance) are briefly addressed in this section. DON's more extensive evaluation of these modifying criteria will be documented in the ROD, once formal comments have been received on this RFS and the new proposed plan and a final remedy selection decision is made.

6.1 COMPARATIVE ANALYSIS OF ALTERNATIVES FOR IR SITE 40

6.1.1 Overall Protection of Human Health and the Environment

6.1.2 Compliance with ARARs

6.1.3 Long-Term Effectiveness and Permanence

6.1.4 Reduction of Toxicity, Mobility, or Volume through Treatment

6.1.5 Short-Term Effectiveness

6.1.6 Implementability

6.1.7 Cost Effectiveness

6.1.8 State Acceptance

6.1.9 Community Acceptance

6.1.10 Conclusions

R-6.2 COMPARATIVE ANALYSIS OF THE REVISED ALTERNATIVES FOR IR SITE 70

This section provides a revised comparative analysis of IR Site 70 remedial alternatives (Table R-6-3).

R-6.2.1 Overall Protection of Human Health and the Environment

The no action alternative would not be fully protective of human health and the environment. Each of the other retained alternatives meets the threshold criteria of overall protection of human health and the environment.

R-6.2.2 Compliance With ARARs

ARARs are not applicable to Alternative 1. Each of the other retained alternatives meets the threshold criteria of compliance with ARARs. However, special provisions may be applicable for the DNAPL area. A "containment zone" approach per 23 CCR Division 3, Chapter 22 §2911 may be necessary. This containment zone can be created through hydraulic and/or reactive barriers to migration.

Table R-6-3
Comparative Analysis of Alternatives by Balancing Criteria
IR Site 70

Alternative*	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost-Effectiveness
Summary of Criteria	Impact of a remedial alternative in the long term, defined as the time after RAOs are met. Consider magnitude of residual risk at the completion of remedial activities; type, degree and adequacy of long-term management from contaminants remaining on-site; long-term reliability of engineering/institutional controls; potential need to replace components and continuing need for repair/maintenance.	CERCLA preference for technologies that permanently and significantly reduce the toxicity, mobility, or volume of hazardous substances. Consider treatment processes used; amount of hazardous material to be treated; degree of expected reduction in toxicity, mobility, or volume; degree to which treatment is irreversible; and type and quantity of treatment residuals.	How an alternative affects human health and the environment from planning until RAOs are achieved. Consider short-term risks to community; potential impacts on workers during construction and O&M; potential environmental impacts of the action; and amount of time required before RAOs are achieved (i.e., the duration of the short term).	Technical and administrative feasibility. Consider technical feasibility, including constructability; operational reliability; ability to take alternative remedial actions in the future; ability to monitor effectiveness. Consider ability to obtain governmental approvals. Consider availability of services and materials, including time needed to develop new or innovative technologies under consideration.	Per the NCP, a remedy is cost-effective if its costs are proportional to its effectiveness. Consider capital cost, including both direct and indirect cost, O&M costs, and net present value of capital and O&M costs.
Alternative 1 – No Action	**Low** Under this alternative, there would be no method of assessing long-term effectiveness and permanence.	**Low** No active treatment is performed and no means are available to monitor natural attenuation processes.	**Low** Natural attenuation processes would not be effective in the short term.	**High** Easy to implement	**Medium** Low cost, but not effective
Alternative 6 – Hydraulic Containment (dissolved plume) and *In Situ* Treatment (DNAPL area)	**Moderately High** In situ chemical oxidation (ISCO) is a very aggressive form of treatment and should result in lower residual risks in the DNAPL area. Containment of the dissolved phase is a very slow process with mixed results.	**Medium** Modeling indicates 1,100 lb dissolved/sorbed TCE removed within the first year by *in situ* chemical oxidation treatment and 1,800 lb removed by pumping in 30 years. Potential impacts due to pumping of the aquifer (i.e. TDS, salt water intrusion).	**Medium** Groundwater modeling indicates RAOs may be achievable within 50 years.	**Low** Design of chemical oxidation will require bench- and pilot-scale testing. Buffering capacity and TDS of aquifer may interfere with process. Potential for vigorous chemical reactions exists.	**Moderately Low** Capital costs are high; however, permanent destruction of VOCs in DNAPL area would provide low cost in proportion to effectiveness.
Alternative 7 – Hydraulic Containment (dissolved plume) and Pump and Treat (DNAPL area)	**Low** Pump and treat has not been shown as a viable treatment alternative for DNAPL. Hydraulic containment of the dissolved phase plume requires an extensive time period.	**Low** Modeling indicates 2,300 lb dissolved/sorbed TCE removed by pumping in 30 years. Pump and treat ineffective on DNAPL. Expect significant impacts to aquifer from pumping	**Low** Groundwater modeling results indicate RAOs are not achieved within 50 years.	**Medium** Demonstrated technology; however, must be carefully designed to minimize disruption to active base operations. Trenching around utilities may be necessary.	**Medium** Low capital costs, but cost in proportion to effectiveness may be questionable
Alternative 9 – Pump and Treat (dissolved plume) and *In Situ* Treatment (DNAPL area)	**Moderately High** Chemical oxidation is a very aggressive form of treatment and should result in lower residual risks in the DNAPL area. The long term pump and treat of the dissolved phase plume is slow and significantly impacts the aquifer (TDS).	**Moderately High** Modeling indicates 1,100 lb dissolved/sorbed TCE removed within the first year by ISCO treatment and 1,900 lb removed by pumping in 10 years. Expect significant impacts to aquifer from pumping.	**Medium** Groundwater modeling indicates RAOs may be achievable within 50 years. Aggressive pumping of the dissolved plume makes MNA in this portion of the plume viable within 15 years. High risks to site workers and facility with ISCO components.	**Low** Design of chemical oxidation will require bench- and pilot-scale testing. Buffering capacity and TDS of aquifer may interfere with process. Potential for vigorous chemical reactions exists. Large volume of pumped groundwater to handle and pipe.	**Moderately High** Capital costs are high; however, permanent destruction of VOCs in DNAPL area would provide low cost in proportion to effectiveness.
Alternative 10 – Pump and Treat (dissolved plume) and Pump and Treat (DNAPL area)	**Medium** This alternative relies on pump and treat and MNA to complete the remediation of residual contamination in the DNAPL area, which may be in the form of contaminants sorbed to the aquifer substrate.	**Medium** Modeling indicates 2,400 lb dissolved/sorbed TCE removed by pumping in 10 years. Expect significant impact to aquifer from salt water intrusion which will impact treatment costs due to fouling.	**Low** Groundwater modeling results indicate RAOs are not achieved within 50 years in all areas.	**Medium** Demonstrated technology; however, must be carefully designed to minimize disruption to active maintenance operation. Trenching around utilities may be necessary.	**Low** Low capital costs, but cost in proportion to effectiveness may be questionable.

Table R-6-3 (continued)
Comparative Analysis of Alternatives by Balancing Criteria
IR Site 70

Alternative*	Long-Term Effectiveness and Permanence	Reduction of Toxicity, Mobility, or Volume Through Treatment	Short-Term Effectiveness	Implementability	Cost-Effectiveness
Alternative 11 – Biobarriers (dissolved plume) and Biostimulation – Bioaugmentation (DNAPL area)	**High** Enhanced bioremediation is a very aggressive form of treatment that has been shown effective in treating both DNAPL and dissolved phase plumes, while allowing subsequent MNA	**High** Testing under the EPA SITE program has demonstrated DNAPL destruction of up to 98% of the mass within one year using bioaugmentation with KB-1™. Dissolved phase COC destruction has been shown too.	**High** Groundwater modeling indicates RAOs may be achievable within 15 years. Enhanced bioremediation is immediately compatible with MNA. Site workers exposed to minimal hazards.	**Medium** Innovative technical application will require some treatability studies. Require a large number of injection well points. Possible biofouling and groundwater flow issues may impact the implementation and operation.	**High** Lowest total costs, but high capital costs for injection points. Highest net present value costs reflect implementation costs. Permanent destruction of COC's in both DNAPL and dissolved phase plume a plus. Costs for converting to MNA after pump and treat has not been included in the current costs for pump and treat.
Comments	All the alternatives (except No. 1 and 11) rely on pumping to remove contamination in the dissolved plume which may impact the aquifer (salt water intrusion). All remedial actions rely on MNA to some extent to achieve RAOs, yet ISCO may not be compatible with MNA. At the completion of MNA, there should be little need for ongoing institutional controls. When RAOs are achieved, it is anticipated that no further monitoring/maintenance would be needed	An estimated 3,300 lb of dissolved/sorbed TCE is present, and unknown quantities of DNAPL may also be present. Chemical oxidation of the DNAPL area rates are higher than pump and treat for the DNAPL area, and aggressive pump and treat rates are higher than hydraulic containment for the dissolved plume under this criterion. Enhanced bioremediation has been shown to destroy both sorbed and dissolved phase COC's.	The enhanced bioremediation approach is a low energy but highly effective method to dechlorinate the site that does not pose short term risks to the community, workers, the environment, and the site facilities. None of the alternatives poses short-term risks to the community or differs in terms of environmental impacts. Chemical oxidation poses some short term worker risk but would reduce risks to O&M workers by reducing duration. Pump and treat poses significant risk to the aquifer due to salt water intrusion.	Enhanced bioremediation does not require significant impacts to the site or large above ground treatment systems (piping, containment, etc.) The alternatives which involve pumping for contaminant mass removal and/or hydraulic containment are demonstrated technology (but extremely long duration). Implementability for alternatives with chemical oxidation and bioremediation are rated lower because of the need to conduct bench- and pilot-scale testing. Chemical oxidation also has the potential for chemical interferences and a complicated (and reactive) reagent delivery system.	Alternatives involving pump and treat of the DNAPL area may need to be operated beyond the assumed 50-year project life, increasing O&M costs. Alternatives implementing significant pumping for containment or treatment may also require significant cost growth for a pretreatment phase if salt water intrusion impacts the carbon treatment efficiency.

Note:
* MNA and institutional controls are included in all alternatives except Alternative 1 (no action)

Acronyms/Abbreviations:
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
DNAPL – dense nonaqueous-phase liquid
IR – Installation Restoration (Program)
lb – pound
MNA – monitored natural attenuation
NCP – National Oil and Hazardous Substances Pollution Contingency Plan
O&M – operation and maintenance
RAO – remedial action objective
TCE – trichloroethene
TDS – total dissolved solids
VOC – volatile organic compound

R-6.2.3 Long-Term Effectiveness and Permanence

Long-term effectiveness and permanence evaluates the magnitude of the residual risk to human and environmental receptors from remaining COC-impacted groundwater contaminants *at the completion of remedial activities*. The alternatives that merely contain the DNAPL area, rather than afford active treatment generally rate lower, because residual contamination may be left upon completion of remedial activities, requiring long-term management and monitoring.

Alternative 11 rates high in long-term effectiveness and permanence. The enhanced bioremediation of the DNAPL and dissolved phase plume is expected to permanently destroy a significant mass of contamination. Enhanced bioremediation is capable of dechlorinating sorbed and free-phase components of the plume. In addition, the enhanced bioremediation will inoculate the aquifer and provide enhanced natural attenuation at the end of the active treatment phase. Because the enhanced bioremediation approach is compatible with and synergistic to monitored natural attenuation, the transition from the active treatment phase is seamless and requires no additional steps. Demonstrations indicate that the enhanced bioremediation can effectively dechlorinate the DNAPL source and the dissolved phase plume. Because the enhanced bioremediation will not require significant pumping of the aquifer there will be less likelihood of secondary impacts such as salt water intrusion. The enhanced bioremediation is anticipated to achieve these results in a reasonable timeframe (15 years).

Alternatives 6 and 9 rate moderately high in long-term effectiveness and permanence. Alternative 6 and 9 provide for chemical oxidation of the DNAPL area, which is expected to permanently destroy a significant mass of contamination and greatly reduce the potential for a continuing source of contamination to the surrounding dissolved plume. Operation of the hydraulic containment and pump and treat systems in the dissolved plume would prevent further migration toward existing water supply points of use. The long term pumping impacts to the aquifer will potentially increase salt water intrusion within the treatment area. The combined approach of chemical oxidation of the DNAPL area and extraction of the dissolved plume is anticipated to lower contaminant levels within the plume such that MNA can proceed within a reasonable timeframe (50 years).

Alternatives 7 and 10 rate medium in long-term effectiveness and permanence. These alternatives would achieve contaminant mass removal in the dissolved plume, but continued containment of the DNAPL area would be necessary to prevent the source area from continuing to act as a source for dissolved contamination.

Alternative 1 rates low in long-term effectiveness and permanence because there would be no remedial activities, no verification of natural attenuation processes, and no monitoring of plume migration patterns to demonstrate protectiveness.

R-6.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternative 11 rates high in reduction of toxicity, mobility, or volume through effective dechlorination using enhanced bioremediation. Through biostimulation and bioaugmentation of the DNAPL (source area), the mass of contaminants will be reduced and the chlorinated compounds will be reduced to ethenes, a non-toxic end product. Thus the quantity and toxicity of the source area and dissolved phase plumes will be reduced through the enhanced bioremediation treatment. The mobility of contaminants may be altered by the biobarriers but the intent of the remedial design is to allow existing groundwater flow to continue and provide the mechanism for moving contaminants through the treatment stages. MNA will continue to reduce the mass and toxicity of residual contaminants left after the enhanced bioremediation period.

Alternative 9 rates moderately high in reduction of toxicity, mobility, or volume through treatment. Chemical oxidation of the DNAPL area would permanently destroy a significant mass of contamination and greatly reduce the potential for a continuing source of contamination to the surrounding dissolved plume. Pump and treat of the dissolved plume would remove significant contaminant mass, which should ultimately be destroyed through off-site thermal carbon regeneration. The proximity of the salt water intrusion boundary to the site creates a potential negative impact due to the extraction of groundwater by pump and treat. This potential increase in total dissolved solids due to salt water intrusion may increase the contaminants within the groundwater, thus increasing the toxicity. MNA would further reduce contaminant mass and volume.

Alternative 6 rates medium in reduction of toxicity, mobility, or volume through treatment. Chemical oxidation of the DNAPL area would permanently destroy a significant mass of contamination and greatly reduce the potential for a continuing source of contamination to the surrounding dissolved plume. Contamination would migrate toward the containment system, where it would be removed and permanently destroyed through off-site thermal carbon regeneration. MNA would further reduce contaminant mass and volume.

Alternative 10 rates medium in reduction of toxicity, mobility, or volume through treatment. Alternative 10 would achieve aggressive contaminant mass removal in the dissolved plume. The containment system for the DNAPL area would also accomplish mass removal of dissolved-phase contamination. Contaminants would be removed and permanently destroyed through off-site thermal carbon regeneration. MNA would further reduce contaminant mass and volume.

Alternative 7 rates low in reduction of toxicity, mobility, or volume through treatment. Alternative 7 would achieve contaminant mass removal in the dissolved plume as contamination migrates toward the containment system. The containment system for the DNAPL area would also accomplish mass removal of dissolved-phase contamination. Contaminants would be removed and permanently destroyed through off-site thermal carbon regeneration. MNA would further reduce contaminant mass and volume.

Alternative 1 rates low in reduction of toxicity, mobility, or volume through treatment. Although modeling results have indicated the plume would continue to migrate at depth and some natural attenuation processes would occur, there would be no way to verify this.

R-6.2.5 Short-Term Effectiveness

Each of Alternatives 6, 7, 9, 10, and 11 would achieve a significant level of short-term effectiveness by containing contaminated groundwater and preventing exposure through institutional controls.

Alternative 11 rates highest in the short-term effectiveness, because the treatment step is *in situ* and a significant quantity of the VOC mass in the groundwater would be dechlorinated through the enhanced bioremediation. Tests have shown relatively high destruction rates for DNAPL under bioaugmented conditions. The chemical reaction in this process is not as extreme as the ISCO and thus is significantly safer to implement. The rate of degradation can be quite high based on studies at other sites. By altering the spacing, density of wells, and biobarrier locations, the treatment rate can be modified to enhance the degradation rate. The enhanced bioremediation will require the installation of injection wells, monitoring wells, groundwater extraction wells, and temporary pipeline conveyance to the well heads from the mixing and distribution point. The groundwater extraction wells will be used to supply site groundwater for mixing with the EVO. These short term exposure scenarios would pose relatively minor exposure risks to workers and the community with proper application of mitigation measures. The short duration for mixing groundwater with the electron donor and re-injecting is the most significant exposure path for human contact with groundwater. This short-term risk can be mitigated through proper design, site specific health and safety plan, and the remedial action work plan. During the majority of the time for remediation, virtually all exposure paths are limited due to the *in situ* nature of the remedial action. Groundwater modeling indicates that RAOs may be achievable within 15 years.

Alternative 9 rates medium in short-term effectiveness. A significant quantity of the VOC mass in the groundwater would be rendered chemically inert within the first year of implementation. Groundwater modeling indicates RAOs may be achievable within 30 years. Aggressive pumping in the dissolved plume accelerates the cleanup timeframe. There are short-term risks associated with chemical oxidation, including potential for vigorous reactions with the chemically buffered, alkaline groundwater and human contact with process chemicals; however, these risks could be mitigated through proper design and the site-specific health and safety plan and remedial action work plan. Operation of the pump-and-treat system for the dissolved plume would reduce the mass of VOC contamination. The impacts of long term pumping on water quality have two potential short term impacts on treatment; 1) increased salt in the groundwater will negatively impact the carbon loading and may require a pretreatment step; 2) pumping 800 acre feet of water per year in close proximity to the coast may exacerbate the salt water intrusion within the aquifer. The installation of monitoring wells, extraction wells, conveyance pipelines, and the treatment plant would pose relatively minor risks to workers and the surrounding community.

Alternative 6 rates medium in short-term effectiveness, because a significant quantity of the VOC mass in the groundwater is rendered chemically inert within the first year of implementation. Groundwater modeling indicates RAOs may be achievable within 50 years. As with Alternative 9, there are short-term risks associated with the chemical oxidation technology. Operation of the containment system for the dissolved plume would prevent further migration of contamination. Implementation of the pump and treat technology may degrade the aquifer due to salt water intrusion as with Alternative 9. Installation of monitoring wells, extraction wells, conveyance pipelines, and the treatment plant would pose relatively minor risks to workers and the surrounding community.

Alternatives 7 and 10 are rated low in terms of effective options in the short term. Operation of the containment and pump-and-treat systems would prevent further migration of the contaminant plume and significantly reduce the volume and mass of VOC contamination in the dissolved plume. However, groundwater modeling indicates these alternatives would fail to achieve RAOs within a 50-year timeframe. The presence of DNAPL could prolong cleanup for an extended duration. Implementation of the pump and treat technology may degrade the aquifer due to salt water intrusion as with Alternative 9. Installation of monitoring wells, extraction wells, conveyance pipelines, and the treatment plant would pose relatively minor risks to workers and the surrounding community.

Alternative 1 rates lowest in short-term effectiveness. No control of land would be exercised and the potential for extraction and use of contaminated groundwater would exist. No containment of contaminated groundwater would be accomplished. Existing natural attenuation processes would not reduce contamination in the short term.

R-6.2.6 Implementability

Alternative 1 rates highest in implementability because there would be no field construction or other remedial activities.

Alternative 11 is technically feasible and is rated medium in difficulty. Alternative 11 will require conventional wells for injection, blending manifolds for EVO and KB-1™ injection, and monitoring wells for evaluating the treatment. No difficulties are anticipated for shipping, installation, application, and evaluation of the bioaugmentation treatment process. The process uses conventional drilling equipment and components for the treatment system. Treatability studies are required to provide design details, not to assess the feasibility or applicability of the technology.

The technical feasibility of Alternative 7 and Alternative 10 rate medium, because both would employ reliable, widely available technologies. Each alternative would be installed using conventional equipment and construction methods. No difficulties are anticipated with regard to reliability or scheduling.

Alternatives 6 and 9 rate low in implementability. The chemical oxidation technology is considered innovative, and bench- and pilot-scale testing would be necessary to verify implementability. Site conditions at the base, specifically the alkalinity, TDS, and sulfate in the shallow groundwater, raise concerns about possible chemical interferences. The alkalinity levels in the groundwater are at the upper range of the vendor's capabilities. Furthermore, there are only three currently known vendors of the chemical oxidation technology and a limited number of experienced contractors in this remedial technology. Careful consideration would need to be given to process design to avoid impacts to overlying structures and utilities in the area.

R-6.2.7 Cost Effectiveness

Table R-6-4 shows estimated costs for the six remedial alternatives. The cost estimates for Alternatives 1, 6, 7, and 10 have been escalated from the 1999 prices using a 3 percent increase per year. The cost for Alternative 9 has been revised based on a process optimization analysis provided to the DON in 2004. Costs for Alternative 11 were developed by using 2005 costing data. Costs for Alternative 1 are zero and will not be evaluated further.

Alternative 7 is the lowest in capital cost. Capital costs are lowest among the remaining alternatives because the hydraulic containment approach minimizes the number of well installations required. O&M costs are lower than Alternative 10 because the flow rates required for hydraulic containment of the dissolved plume are less than for aggressive pumping and treating in this portion of the plume.

Alternative 10 is the next lowest in capital cost. Alternative 10 would incur higher capital costs than Alternative 7 due to the additional well installations for aggressive pump and treat of the dissolved plume and DNAPL plume. Activated carbon usage would be greater with the higher flow rate and high concentrations from the DNAPL area. O&M costs are higher than Alternative 7 during the first 15 years, when combined pumping of the DNAPL area containment system and the dissolved plume pump and treat system results in significantly higher flow rates, which must be extracted and treated. This treatment option may require a pre-treatment step for high total dissolved solids (TDS) water due to the proximity of salt water within the aquifer.

Alternative 6 has the next lowest capital cost. Because the number of wells required for containment is less than for pump and treat, Alternative 6 will require fewer wells. The cost for ISCO wells in the DNAPL area increases the capital cost for this alternative. Capital costs associated with chemical oxidation of the DNAPL area contribute to the higher costs, which include installation of chemical delivery systems, reagent material costs, and operational labor. Because the containment pump and treat system is designed for a lower volume of groundwater, the need for high TDS pretreatment may be minimized.

Table R-6-4
Summary of Cost Estimates for IR Site 70 Remedial Alternatives (Revised)

Alternative	Estimated Duration (years)	Total Direct Capital Cost	Total Direct O&M Cost	Total Cost***	Net Present Value
Alternative 1, no action	25-47	$0	$0	$0	$0
Alternative 6, hydraulic containment (dissolved plume) and *in situ* treatment (DNAPL area)	25-47	$3.5 million*	$5.2 million*	$24.2 million*	$11.0 million*
Alternative 7, hydraulic containment (dissolved plume) and pump and treat (DNAPL area)	50	$831,200*	$6.3 million*	$23.9 million*	$6.7 million*
Alternative 9, pump and treat (dissolved plume) and *in situ* treatment (DNAPL area)	46	$7.9 million**	$10.1 million**	$21.6 million**	$12.1 million**
Alternative 10, pump and treat (dissolved plume) and pump and treat (DNAPL area)	50	$1.3 million*	$6.6 million*	$26.8 million*	$8.5 million*
Alternative 11, Biostimulation - bioaugmentation (DNAPL area) and bioaurgmented biobarriers (dissolved plume)	15	$4.3 million	$11.4 million	$18.8 million	$14.7 million

Notes:
Highlighted values indicate the lowest cost for that project element and use revised cost estimates based on 2005 dollars
* indicate price with a 3% per year cost increase to reflect current 2004 pricing
** indicate BNI revised estimates from the "White Paper – Alternative Technology Evaluation IR Site 70, NAVWPNSTA Seal Beach" June 2004
*** Includes 20% Contingency

Acronyms/Abbreviations:
IR – Installation Restoration (Program)
DNAPL – dense nonaqueous-phase liquid
O&M – operation and maintenance

Alternative 11 has the next lowest capital cost. The higher cost is primarily driven by the amount of oil and related injection labor required to create the biobarriers, and the need for a limited number of reinjections throughout the treatment period. Another significant cost is the number of well points that are being drilled to provide the injection points and monitoring data. Well installation costs may be reduced by achieving a larger radius of oil injection allowing greater spacing between wells along the biobarriers; however, targeting a larger radius of influence requires more oil to achieve the same lateral coverage, thus increasing oil costs exponentially. The cost of well installations must therefore be balanced with the cost of the oil to achieve that same coverage along the biobarrier. Costs will also be impacted by the number of biobarriers required and the targeted treatment duration. Higher groundwater velocities than estimated and/or greater natural attenuation rates would result in fewer required biobarriers. A longer targeted treatment duration would also allow for fewer biobarriers to be used; however, these barriers would have to be sustained over the entire period, requiring more injections per barrier. Again, there is a balance between the optimal remediation duration and barrier spacing. A significant uncertainty in the remedial design that will impact the cost estimate is the lifespan of the oil. Current estimates from initial tests appear to indicate typical lifespans of at least one to two years. Oil lifespan will also be impacted by the electron acceptor loading (e.g., contaminants, sulfate, nitrate, etc.), the dissolution rate of the oil, and the rate of groundwater flux through the bioactive zone and is, thus, somewhat site specific.

Alternative 9 is the most expensive in capital expenditures. Higher capital costs are associated with the chemical oxidation treatment of the DNAPL area, the number of injection points required for ISCO, and installation of the well field for aggressive pump and treat of the dissolved plume. The high flow volume of the pump and treat will also require a higher capacity GAC treatment system. Since the higher groundwater pumping rate will potentially cause greater salt water intrusion, the pumped water may require pretreatment to lower the TDS to avoid increased carbon consumption through fouling and clogging.

The estimated O&M costs for most of the alternatives are close except the revised cost for Alternative 9 which includes a pretreatment for high TDS and Alternative 11. Alternative 11 is the highest estimated O&M costs due to extensive monitoring points and 15-year injections of EVO.

Alternative 11 had the lowest estimated total cost over the life of the treatment system and MNA. The duration of the treatment has a significant impact on the remediation costs. Alternative 9 had the next lowest total cost based on a 46-year remediation cycle. Alternatives 7, 6, and 10 show increasing total cost as the remediation period increases and passes the 50 year mark.

Irrespective of the differences in net present-worth costs, Alternatives 1, 6, 7, 9, and 10 are all rated medium in terms of cost-effectiveness due to the extended duration (50 years or more). The *in situ* application of enhanced bioremediation without any significant groundwater extraction provides for a cost effective approach to Site 70 remediation strategy. Although *in situ* treatment results in higher capital costs, Alternatives 9 and 11 are considered cost effective because costs are proportional to effectiveness over the duration of the remedial action.

R-6.2.8 State Acceptance

Alternative 1 is rated low in terms of state acceptance. Based on presentation to date to the regulatory agencies, an enhanced bioremediation alternative should be acceptable to the State. Because formal acceptance has not been received, Alternative 11 is rated medium. Each of the other alternatives is rated medium with regard to this criterion. The

DON believes each of the alternatives complies with ARARs and is protective of human health and the environment.

R-6.2.9 Community Acceptance

Alternative 1 is rated low in terms of community acceptance. Each of the other alternatives is rated medium for this criterion. All of the alternatives prevent off-site migration of contamination. No disruption of surrounding communities would occur and there are no air emission issues.

R-6.2.10 Conclusions

Alternative 11, which includes *in situ* bioremediation of the DNAPL (source area) and dissolved phase plume, scores the highest. The enhanced bioremediation of the DNAPL will be achieved through application of an electron donor to achieve reduced conditions and subsequent bioaugmentation with a stable, halorespiring, dechlorinating microbial culture (KB-1™). Alternative 11 meets the threshold criteria of overall protection of human health and the environment and compliance with ARARs. Table R-6-5 provides a summary of the alternatives with the nine NCP criteria. Alternative 11 rated highest overall among the five balancing criteria when compared with the other five alternatives. Alternative 11 uses an enhanced bioremediation approach to enhance the mass removal rate of DNAPLs in the source area to reduce total cleanup time. The enhanced rate of biological activity required to increase the mass removal rate will be achieved by injecting EVO (electron donor) and the requisite halorespiring microorganisms in the KB-1™ culture throughout the source area. Demonstrations have shown up to 98 percent mass removal within a DNAPL site over one year (EPA, 2004).

The dissolved phase plume will be transected by biobarriers which are injected with electron donor and bioaugmented with KB-1™, a stable, halorespiring microbial consortia capable of dechlorinating TCE to ethenes. Injection well points will be drilled and installed across the dissolved plume at a spacing equal to the radius of influence for that zone. Each biobarrier will be spaced perpendicular to the axis of groundwater flow at a spacing equal to 5 years of groundwater flow. As groundwater flows through the biobarriers the microbial culture will actively dechlorinate the chlorinated compounds. Using the estimated groundwater velocity of 0.5 feet per day the effective unretarded residence time for groundwater to pass through each biobarrier will be approximately 50 days.

Table R-6-5
Summary of IR Site 70 Acceptance Review Criteria (New)

NCP Criteria	Altern. 1	Altern. 6	Altern. 7	Altern. 9	Altern. 10	Altern. 11
Protective of human health and the environment	No (0)	Yes (3)	Yes (3)	Yes (3)	Yes (3)	Yes (3)
Comply with ARARs	NA (0)	Yes (3)	Yes (3)	Yes (3)	Yes (3)	Yes (3)
Long-term Effectiveness	Low (0)	Mod. High (4)	Low (1)	Mod High (4)	Medium (3)	High (5)
Reduce Toxicity, Mobility, or Volume through treatment	Low (0)	Medium (3)	Low (1)	Mod. High (4)	Medium (3)	High (5)
Short-term Effectiveness	Low (0)	Medium (3)	Low (1)	Medium (3)	Low (1)	High (5)
Implementability	High (5)	Low (1)	Medium (3)	Low (1)	Medium (3)	Medium (3)
Cost Effectiveness	NA (0)	Mod. Low (2)	Medium (3)	Mod High (4)	Low (1)	High (5)
State Acceptance	Low (0)	Medium (3)	Medium (3)	Medium (3)	Medium (3)	High (4)
Community Acceptance	Low (0)	Medium (3)	Medium (3)	Medium (3)	Medium (3)	Medium (3)
Total Score (possible 45 score)	Low (5)	Medium (25)	Mod. Low (22)	Mod. High (28)	Medium (22)	Mod. High (34)
Quartile 0-1, 2, 3, 4	**Q-1**	**Q-3**	**Q-2**	**Q-3**	**Q-3**	**Q-3**

Notes:
Score values from 0 – 5, with 0 being lowest and 5 being the highest rating
Mod. = Moderate
NA = Not Applicable/Not Available
ARARs = Applicable, Relevant, and Appropriate Requirements
NCP = National Contingency Plan
Quartile = 1st 1-10 pts, 2nd 11-22 pts, 3rd 23-34 pts, 4th 35-45 pts.

Based on advances in the bioremediation technology, these two approaches for the respective areas are considered a very aggressive remedial strategy. Groundwater modeling indicates that 99% of the dissolved TCE would be removed by *in situ* treatment. Estimates of DNAPL mass removal could not be obtained from the model. Groundwater modeling further indicates RAOs may be achievable within the project life evaluated for this alternative (15 years). The microbial dechlorination of the primary TCE compounds and daughter products to ethene has been demonstrated at IR Site 40. This alternative is the least expensive based on total cost. This alternative is immediately compatible with long term MNA and will actually enhance that process through the distribution of microbial culture and nutrients. A comparison of the alternatives is provided in Table R-6-5

Alternative 9 (pump and treat [dissolved plume] and *in situ* treatment [DNAPL area]) rates second highest overall among the six alternatives. Table R-6-5 indicates that Alternative 9 was the second highest in meeting the balancing criteria and Table R-6-4 shows the alternative had the second lowest total cost. Alternative 9 was selected as the preferred remedy from the original FS. Alternative 9 combines an aggressive *in situ* chemical oxidation treatment option for the DNAPL area with an aggressive pump and treat option for mass removal of dissolved-phase contamination at IR Site 70. Chemical oxidation is a very aggressive form of treatment and should result in lower residual risks in the DNAPL area, following treatment, than some of the other process options evaluated. Groundwater modeling indicates 1,100 pounds of TCE would be removed by *in situ* treatment, along with an additional 1,900 pounds of TCE removed by pumping in 10 years. Groundwater modeling further indicates RAOs may be achievable within the project life evaluated for this alternative (50 years). Aggressive pumping in the dissolved plume should make MNA a viable end-stage plume management strategy within 15 years. This 15-year duration of high rate pumping (approximately 880 acre feet (AF) per year) could have serious negative impacts to the local and regional aquifer due to increased salt water intrusion. In addition, the increased salt content of the treated water will either require pretreatment or increase the consumption of GAC within the treatment system. With regard to the chemical oxidation, potential benefits from reduced duration and permanent reduction in toxicity, mobility and volume would exceed short-term risks to workers and overlying structures. However, the operational reliability of this alternative is rated low due to the need to conduct bench- and pilot-scale testing of the chemical oxidation technology. These factors reduce the overall effectiveness of this approach.

Alternative 6 (hydraulic containment [dissolved plume] and *in situ* treatment [DNAPL area]) rates next highest overall among the balancing criteria. Alternative 6 would use a less aggressive pumping approach for the dissolved plume than Alternative 9. The flow rates for extracted contaminated groundwater resulting from hydraulic containment are approximately half those for Alternative 9. This results in a less expensive approach for the dissolved plume; however, a longer timeframe for pumping is necessary (approximately 30 years) to reduce contamination to levels low enough to revert to MNA. The longer duration, high rate pumping (approximately 440 AF per year) could have serious negative impacts to the local and regional aquifer due to increased salt water intrusion. As mentioned above, increased salt content will negatively impact the treatment system efficiency. Nevertheless, groundwater modeling indicates RAOs may be achievable within 50 years. As for Alternative 9 above, potential benefits from chemical oxidation of the DNAPL area are thought to exceed short-term risks, and operational reliability of this alternative is rated low.

Alternative 10 (pump and treat [dissolved plume] and pump and treat [DNAPL area]) rates the next highest overall, followed by Alternative 7 (hydraulic containment [dissolved plume] and pump and treat [DNAPL area]), among the balancing criteria. In Table R-6-5 Alternative 7 and 10 scored the same at approximately 50 percent of the maximum score. Alternatives 7 and 10 are similar to Alternatives 6 and 9, respectively, in terms of the dissolved-plume remediation approach. However, Alternatives 7 and 10 would use a pump-and-treat approach for the DNAPL area. Groundwater modeling indicates these alternatives would not achieve RAOs within 50 years. Because of the presumed presence of DNAPLs, these alternatives rate lower in terms of long-term effectiveness and short-term effectiveness than Alternatives 6 and 9. Alternatives 7 and 10 use a demonstrated technology to contain contamination and achieve mass removal of dissolved-phase contamination; both rate medium in implementability. Alternatives 7 and 10 are less expensive than Alternatives 6 and 9, but when costs are weighed against effectiveness, Alternatives 7 and 10 rate only medium. The longer duration, high rate pumping (approximately 440 AF per year for Alternative 7 and 880 AF per year for Alternative 10) could have serious negative impacts to the local and regional aquifer due to increased salt water intrusion. As mentioned above, increased salt content will negatively impact the treatment system efficiency.

Alternative 1 is not a viable alternative for IR Site 70 because it does not afford overall protection of human health and the environment. Contaminant migration would not be monitored or contained, and no restrictions on the use of contaminated groundwater would be in place.

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Section R-7
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REVISED APPENDIX R-B

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

FOREWORD

This revised Appendix provides an updated evaluation of applicable or relevant and appropriate requirements (ARARs) to identify and evaluate potential federal and California state ARARs for groundwater at Installation Restoration (IR) Program Site 70, Naval Weapons Station Seal Beach (NAVWPNSTA Seal Beach), Seal Beach, California. Also included in the revised Appendix are the Department of the Navy (DON) determinations regarding those potential ARARs for each remedial alternative retained for detailed analysis in this Revised Feasibility Study (RFS). The Table of Contents (TOC) in this Appendix provides a cross reference between Appendix B in the original Feasibility Study (FS; Bechtel, 2002) and the revised Appendix R-B of the RFS. The shaded portions of the TOC reflect elements of Appendix B of the FS that have not been altered for the RFS; those sections without page numbers listed in the TOC have been incorporated into the RFS by reference. Unshaded portions of the TOC reflect text that has been added or revised within the RFS.

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TABLE OF CONTENTS

TABLES

Table

ACRONYMS/ABBREVIATIONS

bgs	below ground surface
BNI	Bechtel National, Inc.
cm/s	centimeters per second
cm^3/g	cubic centimeters per gram
cm^2/min	square centimeters per minute
3-D	three-dimensional
DCA	dichloroethane
DCE	dichloroethene
De	aqueous diffusion coefficient
DNAPL	dense nonaqueous-phase liquid
ERSE	Extended Removal Site Evaluation
f_{oc}	fraction of organic carbon
FS	feasibility study
ft^{-1}	per foot
ft/day	feet per day
ft^2/min	square feet per minute
g/cm^3	grams per cubic centimeter
g/mole	grams per mole
gpm	gallons per minute
IR	Installation Restoration (Program)
k_d	distribution coefficient
k_{oc}	organic carbon-to-water partitioning coefficient
kg/L	kilograms per liter
lb	pound
lb/ft^3	pounds per cubic foot
µg/L	micrograms per liter
mg/L	milligrams per liter
MSL	mean sea level
NAVWPNSTA	Naval Weapons Station

PCE	tetrachloroethene
TCA	trichloroethane
TCE	trichloroethene
U.S. EPA	United States Environmental Protection Agency
VOC	volatile organic compound
vol. %	volumetric percent
wt. %	weight percent

Revised Appendix R-B

APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS

R-B1 INTRODUCTION

R-B1.1 PURPOSE

The purpose of this evaluation of applicable or relevant and appropriate requirements (ARARs) is to identify and evaluate potential federal and California state ARARs and to set forth the Department of the Navy (DON) determinations regarding those potential ARARs for each remedial alternative retained for detailed analysis in this Revised Feasibility Study (RFS) for groundwater at Installation Restoration (IR) Program Site 70, NAVWPNSTA Seal Beach.

This evaluation is a step in identifying potential ARARs from the universe of regulations, requirements, and guidance that may be pertinent to IR Site 70 as identified by the DON or state agencies. This evaluation includes an initial determination of whether the potential ARARs actually qualify as ARARs, and a comparison for stringency to identify the controlling ARARs. The identification of ARARs is an iterative process. The final determination of ARARs will be made by the DON in the Record of Decision (ROD), after public review, as part of the response action selection process.

R-B1.2 SUMMARY OF CERCLA AND NCP REQUIREMENTS

- Section 121(d) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 states that remedial actions on CERCLA sites must attain (or the decision document must justify the waiver of) any federal or more stringent state environmental standards, requirements, criteria, or limitations that are determined to be legally applicable or relevant and appropriate.
- Applicable requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that specifically address the situation at a CERCLA site. The requirement is applicable if the jurisdictional prerequisites of the standard show a direct correspondence when objectively compared to the conditions at the site. If the requirement is not legally applicable, then the requirement is evaluated to determine whether it is relevant and appropriate. Relevant and appropriate requirements are those cleanup standards, standards of control, and other substantive environmental protection requirements, criteria, or limitations promulgated under federal or state law that, while not applicable, address problems or situations similar to the circumstances of the proposed response action and are well suited to the conditions of the site (United States Environmental Protection Agency [U.S. EPA] 1988a). The criteria for determining relevance and appropriateness are listed in Title 40, *Code of Federal Regulations* (CFR), Section 300.400(g)(2) (40 CFR 300.400[9][2], and include the following:
- the purpose of the requirement and the purpose of the CERCLA action;

- the medium regulated or affected by the requirement and the medium contaminated or affected at the CERCLA site;
- the substances regulated by the requirement and the substances found at the CERCLA site
- any variances, waivers, or exemptions of the requirement and their availability for the circumstances at the CERCLA site;
- the type of place regulated and the type of place affected by the release or CERCLA action;
- the type and size of structure or facility regulated and the type and size of structure or facility affected by the release or contemplated by the CERCLA action; and
- any consideration of use or potential use of affected resources in the requirement and the use or potential use of the affected resource at the CERCLA site

Tables included in this appendix present each potential ARAR with a determination of ARAR status (i.e., applicable or relevant and appropriate). For the determination of relevance and appropriateness, the pertinent criteria were examined to determine whether the requirements addressed problems or situations sufficiently similar to the circumstances of the release or remedial action contemplated, and whether the requirement was well suited to the site. A negative determination of relevance and appropriateness indicates that the requirement did not meet the pertinent criteria. Negative determinations are documented in the tables of this appendix and will be discussed in the text only for specific cases. In order to qualify as a state ARAR under CERCLA and the National Oil and Hazardous Substances Pollution Contingency Plan (NCP), a state requirement must be:

- a state law;
- an environmental or facility siting law;
- promulgated (of general applicability and legally enforceable);
- substantive (not procedural or administrative);
- more stringent than the federal requirement;
- identified in a timely manner; and
- consistently applied.

In order to constitute an ARAR, a requirement must be substantive. Therefore, only substantive provisions of requirements identified as ARARs in this analysis are considered to be ARARs. Section 121(e)(1) of CERCLA states that "No Federal, State, or local permit shall be required for the portion of any removal or remedial action conducted entirely on-site, where such remedial action is selected and carried out in compliance with this section." Permits are considered to be procedural or administrative requirements. Provisions of generally relevant federal and state statutes and regulations that were determined to be procedural or nonenvironmental, including permit requirements, are not considered to be ARARs. The term "on-site" is defined for purposes of this discussion as the areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action.

Nonpromulgated advisories or guidance issued by federal or state government are not legally binding and do not have the status of ARARs. Such requirements may, however, be useful, and are "to be considered" (TBC). These requirements complement ARARs, but do not override them. They are useful for guiding decisions regarding cleanup levels or methodologies when regulatory standards are not available.

Pursuant to U.S. EPA guidance, ARARs are generally divided into three categories: chemical-specific, location-specific, and action-specific requirements. This classification was developed to aid in the identification of ARARs; some ARARs do not fall precisely into one group or another. ARARs are identified on a site basis for remedial actions where CERCLA authority is the basis for cleanup.

As the lead federal agency, the DON has primary responsibility for identification of federal ARARs at NAVWPNSTA Seal Beach. Potential federal ARARs that have been identified for the IR Site 70 RFS are discussed below. Pursuant to definition of the term "on-site" (i.e., areal extent of contamination and all suitable areas in very close proximity to the contamination necessary for implementation of the response action) in 40 CFR 300.5, the on-station areas that are part of this action and the volatile organic compound (VOC) plume extending downgradient of the IR Site 70 boundary are considered to be on site for purposes of this ARARs analysis. The shallow upgradient portion of the IR Site 70 plume that may extend off-station is considered part of the site. Extraction wells, VOC treatment facilities, injection wells, and conveyance systems connecting those items are defined as "on site." Alternatives that include discharge of treated groundwater to independent water purveyors and any additional treatment, blending, and distribution performed by the purveyor are considered to be off-site actions. Therefore, regulatory requirements that apply to off-site actions are not ARARs.

Identification of potential state ARARs was initiated through DON requests that the California Environmental Protection Agency (Cal-EPA) Department of Toxic Substances Control (DTSC) identify potential state ARARs as described in more detail in Section R-B1.3.2. Potential state ARARs that have been identified for IR Site 70 are discussed below.

R-B1.3 DESCRIPTION OF METHODOLOGY

The process of identification and evaluation of potential federal and state ARARs is described in this subsection.

R-B1.3.1 General

In preparing this ARARs analysis, the DON undertook the following measures, consistent with CERCLA and the NCP:

- identified federal ARARs for each remedial action alternative addressed in the RFS, taking into account site-specific information for IR Site 70
- reviewed potential state ARARs identified by the state in order to determine whether they satisfy CERCLA and NCP criteria that must be met in order to constitute ARARs;
- evaluated and compared federal ARARs and their state counterparts in order to determine which state ARARs are more stringent or are in addition to the federal ARARs; and
- reached a conclusion as to which federal and state ARARs were the most stringent and/or "controlling" ARARs for each alternative.

As outlined in Section 2.2 of the original FS report (Bechtel, 2002), the remedial action objectives for the IR Site 70 groundwater action are to:

- protect the existing beneficial uses of the shallow aquifer underlying NAVWPNSTA, Seal Beach, to the extent practicable while minimizing VOC migration (as defined by the RAOs) beyond the current NAVWPNSTA Seal Beach boundaries; and
- protect human health by preventing extraction of VOC-affected shallow groundwater for domestic use until site cleanup goals are achieved.

Remedial action alternatives retained for detailed analysis in this RFS are designed to accomplish these remedial action objectives. Removal and containment of VOCs in groundwater is achieved within the various Alternatives for Site 70 through destruction *in situ* through either bioremediation, monitored natural attenuation, or chemical oxidation processes, and containment through groundwater extraction wells. Appropriate treatment of the extracted groundwater waste stream is included for each alternative, if necessary.

The IR Site 70 remedial action alternatives considered for detailed analysis, and for which an ARARs analysis is presented in this appendix, are as follows:

- Alternative 1 – no action;
- Alternative 6 – hydraulic containment (dissolved plume) and *in situ* treatment (dense nonaqueous-phase liquid [DNAPL] area);
- Alternative 7 – hydraulic containment (dissolved plume) and pump and treat (DNAPL area);
- Alternative 9 – pump and treat (dissolved plume) and *in situ* treatment (DNAPL area);
- Alternative 10 – pump and treat (dissolved plume) and pump and treat (DNAPL area); and
- Alternative 11 – biostimulation combined with bioaugmentation (DNAPL area) and bioaugmented biobarriers (dissolved plume).

R-B1.3.2 Identification and Evaluation of State ARARs

The process of identification and evaluation of potential state ARARs by the state and the DON is described in this subsection.

B1.3.2.1 SOLICITATION OF STATE ARARS UNDER NCP

U.S. EPA guidance recommends that the lead federal agency consult with the state when identifying state ARARs for remedial actions. The DON followed the procedures of the process set forth in 40 CFR Section 300.515 and Section 7.6 of the Federal Facilities Agreement (FFA) for remedial actions in seeking state assistance in identification of state ARARs.

In essence, the CERCLA/NCP/FFA requirements for remedial actions provide that the lead federal agency (DON, in this case) request that the state identify chemical-specific and location-specific state ARARs upon completion of site characterization, and again request identification of all categories of state ARARs (chemical specific, location specific, and action specific) upon completion of identification of remedial alternatives for detailed analysis. The state must respond within 30 days of receipt of the lead federal agency requests.

R-B1.3.2.2 CHRONOLOGY OF EFFORTS TO IDENTIFY STATE ARARS

The following chronology summarizes DON efforts to obtain state assistance in identification of state ARARs for the remedial action at NAVWPNSTA Seal Beach. Key correspondence between the DON and the state agencies relating to this effort has been included in the Administrative Record (AR) for this interim action.

- DON formally requested state chemical-, location-, and action-specific ARARs for the RFS at IR Site 70 groundwater on 29 October 2004. Letters were sent to the DTSC (SWDIV, 2004a) soliciting ARARs based on preliminary remedial technologies and process options detailed to the agencies by the DON.
- Following the DON solicitation for ARARs from DTSC, DTSC requested action-specific, chemical-specific, and location-specific ARARs in a letter dated 2 December 2004.
- DON received a letter from DTSC (DTSC, 2005) providing its chemical-, location-, and action-specific ARARs on 19 January 2005.
- DTSC (DTSC, 2005) provided a list of potential chemical- and location-specific ARARs to be considered for IR Site 70. The list included responses from the Air Resources Board; RWQCB, Santa Ana; Department of Fish and Game; California Department of Transportation; and the South Coast Air Quality Management District (SCAQMD).

This RFS ARAR analysis addresses the potential state ARARs identified in the above correspondence from Cal-EPA DTSC and RWQCB and in codes and regulations from the following state and local agencies and departments:

- California Department of Transportation;

- California Air Resources Board;
- California Department of Fish and Game;
- SCAQMD; and
- California RWQCB, Santa Ana Region.

R-B2 CHEMICAL-SPECIFIC ARARS

Chemical-specific ARARs are generally health- or risk-based numerical values or methodologies applied to site-specific conditions that result in the establishment of numerical values. Many potential ARARs associated with particular remedial alternatives (such as closure or discharge) can be characterized as action-specific ARARs, but include numerical values or methodologies to establish them so they fit in both categories of ARARs. To simplify the comparison of numerical values, some action-specific ARARs with numerical values are discussed in this section.

ARARs determination conclusions addressing numerical values are presented for groundwater. A summary of the ARARs conclusions and a more detailed discussion of the ARARs for groundwater are presented below.

Potential federal and state chemical-specific ARARs are summarized in Tables R-B2-1 and R-B2-2, respectively.

R-B2.1 SUMMARY OF ARARS CONCLUSIONS BY MEDIUM

Groundwater, surface water, air, and soil are the environmental media potentially affected by the IR Site 70 remedial actions. The conclusions for ARARs pertaining to these media are presented in the following sections.

R-B2.1.1 Groundwater ARARs Conclusions

The contaminants of concern in IR Site 70 groundwater for this action are the VOCs that were detected during groundwater sampling conducted during the Extended Removal Site Evaluation (ERSE) (BNI 1999).

Table B2-3 lists the VOCs identified as the contaminants of concern in the groundwater. If additional VOCs or other organic compounds are detected in the future during monitoring programs, they will be addressed in the final ROD.

The substantive provisions of the following requirements are the most stringent of the potential federal and state groundwater ARARs and TBCs for the action:

- Water Quality Control Plan (WQCP) for the Santa Ana River Basin (8) (RWQCB 1995) (water quality objectives [WQOs], beneficial uses, waste discharge limitations);
- federal maximum contaminant levels (MCLs) and nonzero maximum contaminant level goals (MCLGs) for organic compounds;

Table R-B2-1
Potential Federal Chemical-Specific ARARs by Medium [a]

Requirement	Prerequisite	Citation	ARAR Determination	Comments
		GROUNDWATER		
Safe Drinking Water Act, 42 USC 300 [b]				
National primary drinking water standards are health-based standards for public water systems (MCLs)	Public water system.	40 CFR 141.11 - 141.16, excluding 141.11(d)(3); 40 CFR 141.60 - 141.63	Relevant and appropriate	The NCP defines MCLs as relevant and appropriate for groundwater determined to be a current or potential source of drinking water in cases where MCLGs are not ARARs. MCLs are relevant and appropriate for Class II aquifers such as the Santa Ana Pressure Subbasin. The RWQCB has designated the Orange County Management Zone for municipal/domestic use (potential drinking water) in addition to other uses, and these designations also apply to the shallow groundwater system at NAVWPNSTA Seal Beach. Only the primary standards for organic chemicals (40 CFR 141.61), specifically VOCs, are identified as ARARs for this RFS. MCLs are not ARARs for those constituents that NAVWPNSTA Seal Beach has not contributed to the shallow groundwater system (e.g., inorganics such as arsenic and nitrate).
MCLGs pertain to known or anticipated adverse health effects (also known is recommended MCLs).	Public water system.	Public Law No. 99-339, 100 Statute 642 (1986), and 40 CFR 141 Subpart F	Relevant and appropriate	MCLGs that have nonzero values are relevant and appropriate for groundwater determined to be a current or potential source of drinking water (40 CFR 300.430[e][2][i][B]through [D]). Groundwater in the vicinity of WPNSTA, Seal Beach is designated for municipal/domestic use (potential drinking water). Nonzero MCLGs exist for some Site 70 VOCs of concern.
National secondary drinking water regulations are standards for the aesthetic qualities of public water systems (SMCLs).	Public water system	40 CFR 143, excluding 143.5(b)	Not an ARAR	SMCLs are not ARARs because they are nonenforceable federal guidelines intended for the states.
Clean Water Act, 33 USC 1251 et Seq. [b]				
Water quality criteria.	CERCLA response actions addressing groundwater.	33 USC 1314(a) and 42 USC 9621 (d)(2)	Not an ARAR	The NCP (40 CFR 300.430[3] states that FAWQC are potentially relevant and appropriate for groundwater only in the absence of promulgated MCLs and MCLGs. In such cases, the FAWQC may be adjusted to reflect only drinking water use to develop remedial goals. This is consistent with the intent of the NCP.

Table R-B2-1 (continued)
Potential Federal Chemical-Specific ARARs by Medium [a]

Requirement	Prerequisite	Citation	ARAR Determination	Comments
Resource Conservation and Recovery Act [b]				
Groundwater protection standards: Owners/operators or RCRA TSD facilities must comply with conditions designed to assure that hazardous constituents entering groundwater from a regulated unit do not exceed concentration limits for contaminants of concern set forth under 22 CCR 66264.94 in the uppermost aquifer underlying the waste management area beyond the point of compliance.	Uppermost aquifer underlying a waste management unit beyond the point of compliance; RCRA hazardous waste treatment, storage, or disposal	22 CCR 66264.94, except 66264.94(a)(2), and 94(b)	Relevant and appropriate	Applicable only for regulated TSD facilities. Based on available data, no RCRA-listed hazardous wastes were disposed of at Site 70 and groundwater contamination did not result from release of RCRA-regulated waste. However, substantive provisions of these requirements are relevant and appropriate to site circumstances. VOC constituents in groundwater are similar to those found in RCRA wastes and may be found at concentrations exhibiting the characteristics of toxicity, making this a chemical-specific ARAR for development of site remedial goals.
		SOIL		
Definition of RCRA characteristic hazardous waste.	Waste generation.	22 CCR 66262.11, 66262.2, 66261.3, 66261.100(a)(1), 66261.21, 66261.23, and 66261.24(a)(1)	Applicable	VOC-affected soil that may be excavated at IR Site 70 is not an RCRA-listed hazardous waste and is unlikely to be an RCRA characteristic hazardous waste. However, waste must still be tested for the RCRA hazardous waste characteristics at the point of generation.
		SURFACE WATER		
Comprehensive Environmental Response, Compensation, and Liability Act [b]				
Alternative Concentration Limits	There are known and projected points of entry of groundwater to surface water, there is no statistically significant increase of hazardous consttituents from groundwater in surface water at point of entry, and there are enforceable institutional controls to preclude human exposure at any point between the facility boundary and the point of entry to surface water.	CERCLA Section 122(d)(2)(B)(ii)	Not an ARAR	Applicable as outlined under prerequisites. Allows a risk-based approach to setting alternative concentration limits based on a surface water discharge pathway.

Table R-B2-1 (continued)
Potential Federal Chemical-Specific ARARs by Medium [a]

Requirement	Prerequisite	Citation	ARAR Determination	Comments
Surface water discharge under intent of CERCLA.	Surface water discharge.	CERCLA 121(d)(2)(B) I as codified in 40 CFR 131.36, National Toxics Rule (NTR), 57 *Federal Register* 60848.	Applicable	Applicable limiting discharge levels of waste to surface waters that are consistent with health-based standards for human health or ecological health. FAWQC may be applicable to surface water discharges.

Notes:

[a] Chemical-specific concentrations used for RFS evaluation may not be ARARs indicated in this table, but may be concentrations based upon other factors. Such factors may include the following:
- Human health risk-based concentrations (40 CFR 300.430[e][2][i][A][1] and [2]).
- Ecological risk-based concentrations (40 CER 300.430[e][2][i][G]
- Practical quantitation limits of contaminants (40 CFR 300.430[e][2][i][A][3])

Many potential action-specific ARARs contain chemical-specific limitations and are addressed in the action-specific ARAR tables

[b] Statutes and policies and their citations are provided as headings to identify general categories of potential ARARs for the convenience of the reader. Listing the statutes and policies does not indicate that the Department of the Navy accepts the entire statutes or policies as potential ARARs. Specific potential ARARs are addressed in the table below each general heading; only substantive requirements of the specific citations are considered potential ARARs.

Acronyms/Abbreviations:
- ARAR – applicable or relevant and appropriate requirement
- CCR – *California Code of Regulations*
- CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
- CFR – *Code of Federal Regulations*
- FAWOC – federal ambient water quality criteria
- RFS – Revised Feasibility Study
- IR – Installation Restoration
- MCL – maximum contaminant level
- MCLG – maximum contaminant level goal
- NAVWPNSTA – Naval Weapons Station
- NCP – National Oil and Hazardous Substances Pollution Contingency Plan
- RCRA – Resource Conservation and Recovery Act
- RWQCB – California Regional Water Quality Control Board, Santa Ana Region
- SMCL – secondary maximum contaminant level
- TSD – treatment, storage, and disposal
- USC – *United States Code*
- VOC – volatile organic compound

Table R-B2-2
Potential State Chemical-Specific ARARs by Medium [a]

Requirement	Prerequisite	Citation	ARAR Determination	Comments
		GROUNDWATER		
National drinking water standards for public water systems (state MCLs).	Public water system.	22 CCR 64431 and 64444	Relevant and appropriate	If more stringent than federal MCLs or nonzero MCLGs, state MCLs are relevant and appropriate for groundwater determined to be a source of drinking water. The Orange County Management Zone is a Class II aquifer designated by the RWQCB for municipal and domestic use in addition to other uses. These use designations also apply to the shallow groundwater system at NAVWPNSTA Seal Beach. Only state primary standards for organic chemicals (22 CCR 64444), specifically VOCs, are chemical-specific ARARs for this RFS. MCLs are not ARARs for constituents that NAVWPNSTA Seal Beach has not contributed to the shallow groundwater system (e.g., inorganics such as As, NO_3^-).
Secondary drinking water standards for public water systems (state SMCLs).	Public water system.	22 CCR 64449	Not an ARAR	No SMCL has been identified for site-related VOC contaminants. Also, SMCLs are nonenforceable state requirements and cannot be ARARs according to the NCP.
Use of California-certified laboratory for analysis of water quality samples.	Public water system.	California Water Code, 3 Division 7, Section 13176	Not an ARAR	Non an ARAR, because this only specifies administrative detail regarding the use of a California-certified laboratory.
Report of waste discharge requirements for any existing or proposed discharge of waste to water that may affect the quality of waters of the state.	Public water system	California Water Code, Division 7, Section 13260	Not an ARAR	Not an ARAR, because it is no more restrictive than the CWA and is administrative and procedural.
Administrative enforcement and remedies by regional boards provide administrative framework for enforcement actions against discharges.	Public water system.	California Water Code, Division 7, Section 13300, 13304	Not an ARAR	Not an ARAR, because it is administrative and procedural.
Report of completion of construction, alteration, destruction, or abandonment of well.	Water well construction.	California Water Code, Division 7, Chapter 10, Section 13750.5 to 13755	Not an ARAR.	Not an ARAR, because it is administrative and procedural.
Criteria for waste management units, facilities, and disposal sites.	Waste management unit.	27 CCR, Division 2, Chapter 3, Sections 20380, 20390, 20400, 20405, 20410, 20415	Not an ARAR.	Water quality monitoring and reporting criteria, points of compliance, and concentration limits. No more restrictive than 40 CFR 141.61. Administrative and procedural.

Table R-B2-2 (continued)
Potential State Chemical-Specific ARARs by Medium [a]

Requirement	Prerequisite	Citation	ARAR Determination	Comments
Authorizes the state and regional water boards to establish in water quality plans beneficial uses and numerical and narrative standards to protect both surface and groundwater quality. Authorizes regional water boards to issue permits for discharges to land and surface or groundwater that could affect water quality, including NPDES permits, and to take enforcement action to protect water quality.		California Water Code, Division 7, Sections 13241, 13243, 13263(a), 13269, and 13360 (Porter-Cologne Water Quality Control Act)	ARAR	Other provisions of Porter-Cologne Water Quality Act are not considered substantive by the DON.
State Water Resources Control Board and California Regional Water Quality Control Board, Santa Ana Region [b]				
Describes water basins in Santa Ana Region. Establishes beneficial uses of groundwater and surface water. Establishes water quality objectives, including narrative and numerical standards. Establishes implementation plans to meet water quality objectives and protect beneficial uses, and incorporates statewide water quality control plans and policies.	Public water system.	Water Quality Control Plan for the Santa Ana Basins (Basin Plan) and amendments including R8-2002-0007, R8-2002-0033, R8-2003-0085, and R8-2004-0001.	Applicable	Substantive provisions in Chapters 2 through 4 of the Basin Plan are ARARs. The beneficial uses for the Orange County Management Zone are municipal/domestic use (potential drinking water), agricultural supply, industrial service supply, and industrial process supply. These uses also apply to the shallow groundwater system at NAVWPNSTA Seal Beach.
		GROUNDWATER		
Incorporated into Basin Plan. Requires that high-quality waters be maintained unless certain findings are made. Discharges to high-quality waters must comply with antidegradation provisions. At a minimum, beneficial uses must be maintained.	Public water system.	SWRCB Resolution No. 68-16 (Policy With Respect to Maintaining High Quality Waters in California)	Not a chemical-specific ARAR.	Not applicable to cleanup of contaminated groundwater or potential migration of VOC-affected plumes. However, this requirement is an action-specific ARAR for remedial alternatives involving discharge of treated groundwater. See Section B2.2.2.1 for more discussion.
Incorporated into the Basin Plan. Establishes policies and procedures for oversight of cleanup and abatement activities of waste discharges that affect or threaten water quality. Authorizes RWQCB to require cleanup and restoration of affected water to background conditions. Requires cleanup and abatement actions to conform to SWRCB Resolution No. 68-16 and applicable provisions of 23 CCR Division 3, Chapter 15.	Discharge potentially affecting water quality.	SWRCB Resolution No. 92-49 (Policies and Procedures for Investigation and Cleanup and Abatement of Discharges under Water Code Section 13304.	Not an ARAR.	Not more stringent than 22CCR 66264.94, a federal ARAR. Therefore, this requirement does not quality as a state ARAR under 40 CFR 300.400(g)(4) and CERCLA Section 121(d)(2)(A)(ii). See Section B2.2.2.1 for more discussion.

Table R-B2-2 (continued)
Potential State Chemical-Specific ARARs by Medium [a]

Requirement	Prerequisite	Citation	ARAR Determination	Comments
Incorporated into Basin Plan. Designates all ground and surface waters of the state as potential drinking water except where TDS are greater than 3,000 ppm, the well yield is less than 200 gpd from a single well, the water is a geothermal resource or in a water-conveyance facility, or the water cannot reasonably be treated for domestic use by using either best management practices or best economically achievable treatment practices.	Public water system.	SWRCB Resolution No. 88-63 (Sources of Drinking Water Policy) and RWQCB Resolution No. 89-42.	Applicable	Substantive provisions are ARARs. However, this requirement is not a controlling ARAR since the Basin plan identifies the Orange County Management Zone and the overlying shallow groundwater at NAVWPNSTA Seal Beach as a source of drinking water.
Establishes water quality protection standards for corrective action, including concentrations limits for constituents of concern at background levels unless infeasible to achieve. Cleanup levels greater than background must meet all applicable water quality standards, must be the lowest levels technically and economically achievable, must consider exposure *via* other media, and must consider combined toxicological effects of pollutants.	Waste management.	27 CCR 20380(a); 20400(a), (c), (d), (e), and (g); 20405	Not an ARAR.	Not more stringent than federal regulations at 22 CCR 66264.94 and 66264.95. (See Section B2.2.2.4 for additional discussion.) Therefore, these requirements do not quality as state ARARs under 40 CFR 300.400(g)(4) and CERCLA Section 121(d)(2)(A)(ii).
Regulates permitting and testing of USTs and specifies corrective action requirements for discharges from tanks.		CCR Title 23, Division 3, Chapter 16.	Not an ARAR	Not applicable because leaking USTs are not the source of VOC contamination observed in the Site 70 plume.
		SOIL		
California Environmental Protection Agency Department of Toxic Substances Control [b]				
Definition of non-RCRA hazardous waste.	Waste generation.	22 CCR 66262.11, 66261.2, 66261.3, 66261.101(a)(1) and (a)(2), 66261.22(a)(3) and (a)(4), 66261.24(a)(2) through (a)(8)	Relevant and appropriate	VOC-affected soil that may be removed at Site 70 is unlikely to be a non-RCRA hazardous waste. However, these materials must still be characterized at the point of generation.

Table R-B2-2 (continued)
Potential State Chemical-Specific ARARs by Medium [a]

Requirement	Prerequisite	Citation	ARAR Determination	Comments
		SURFACE WATER		
Discharges to surface water bodies of the state are authorized under the auspices of the regional water boards.		California Water Code, Division 7, Section 13241, 13243, 132663(a), and 13360 (Porter-Cologne Water Quality Control act)	ARAR	Water quality criteria may be relevant and appropriate for discharge of treated groundwater to surface water.
Discharge of treated water to surface waters.		Water Quality Control Plan for the Santa Ana Basin (Basin Plan)	ARAR	Portions of Chapters 2 through 4 are ARARs concerning discharges to surface water.
Discharge of treated waters potentially entering the ocean.		Ocean Plan	ARAR	Linked through the Basin Plan for water quality standards affecting human health and aquatic species health.
		AIR		
Air emissions under the National Ambient Air Quality Standards place source-specific emissions limitations for emissions of particulates, organic compounds, and toxic air pollutants.	Emission restrictions.	Clean Air Act 40 USC 7401 et seq. as South Coast Air Quality Management District Rules 212 and 1303 under the State Implementation Plan	ARAR	Establish emission standards for particulates, organic compounds, hazardous air pollutants, and new sources.
Visible air emissions limited to less than value described by Ringlemann No. 1 or 20 percent opacity for 3 minutes in any hour.	Emission restrictions.	South Coast Air Quality Management District Rule 401	ARAR	Potential action-specific ARAR.
New Source Review of Carcinogenic Air Contaminants. Regulation XIV. Establishes allowable limits based on risk levels.	Emission restrictions.	South Coast Air Quality Management District Rule 1401	ARAR	Potential action-specific ARAR for new stationary sources. Requires BACT to limit emissions.
Prohibitions under Regulation IV, prohibiting air emissions creating nuisance; fugitive dust; particulate matter; solid particulate matter; liquid and gaseous air contaminants; circumvention; fuel combustion contaminants; sulfur content of gaseous, liquid, or fossil fuels; and burning equipment oxides of nitrogen.	Emission restrictions.	South Coast Air Quality Management District, Rules 402, 403, 404, 405, 407, 408, 409, 431.1, 431,2, 431.3, and 474		Not ARARs for action, chemical, or location.

Table R-B2-2 (continued)
Potential State Chemical-Specific ARARs by Medium [a]

Requirement	Prerequisite	Citation	ARAR Determination	Comments
Source Specific Standards, Regulation XI. Excavation of Landfill Sites and Volatile Organic Compound Emissions from Decontamination of Soil.	Emission restrictions.	South Coast Air Quality Management District Rules 1150, 1166	Not an ARAR.	

Notes:

[a] Chemical-specific concentrations used for RFS evaluation may not be ARARs indicated in this table, but may be concentrations based upon other factors. Such factors may include the following:

- Human health risk-based concentrations (40 CFR 300.430[e][2][i][A][1] and [2]).
- Ecological risk-based concentrations (40 CER 300.430[el[2][i][G]
- Practical quantitation limits of contaminants (40 CFR 300.430[e][2][i][A][3])

Many potential action-specific ARARs contain chemical-specific limitations and are addressed in the action-specific ARAR tables

[b] Statutes and policies and their citations are provided as headings to identify general categories of potential ARARs for the convenience of the reader. Listing the statutes and policies does not indicate that the Department of the Navy accepts the entire statutes or policies as potential ARARs. Specific potential ARARs are addressed in the table below each general heading; only substantive requirements of the specific citations are considered potential ARARs.

Acronyms/Abbreviations:

ARAR – applicable or relevant and appropriate requirement
As – arsenic
BACT – best available control technology
CCR – *California Code of Regulations*
CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
CFR – *Code of Federal Regulations*
CWA – Clean Water Act
DON – U.S. Department of Navy
RFS – Revised Feasibility Study
gpd – gallon per day
IR – Installation Restoration
NAVWPNSTA – Naval Weapons Station
MCL – maximum contaminant level
MCLG – maximum contaminant level goal
NCP – National Oil and Hazardous Substances Pollution Contingency Plan
NO3- – nitrate
NPDES – National Pollutant Discharge Elimination System
ppm – parts per million

Table R-B2-2 (continued)
Potential State Chemical-Specific ARARs by Medium [a]

RCRA – Resource Conservation and Recovery Act
RWQCB – California Regional Water Quality Control Board, Santa Ana Region
SMCL – secondary maximum contaminant level
TSD – treatment, storage, and disposal
USC – *United States Code*
UST – underground storage tank
VOC – volatile organic compound

Volatile Organic Compound	U.S. EPA SAFE DRINKING WATER ACT [a] Maximum Contaminant Level	Maximum Contaminant Level Goal	California [b] Maximum Contaminant Level	Controlling ARAR
Acetone	---	---	---	---
Benzene	5	0	1	1
Carbon disulfide	---	---	---	21[c]
Carbon tetrachloride	5	0	0.5	0.5
Chlorobenzene	100	100	70	70
Chloroform	100	0	100	100
1,1-dichloroethane	---	---	5	5
1,2-dichloroethane	5	0	0.5	0.5
1,1-dichloroethene	7	7	6	6
cis-1,2-dichloroethene	70	70	6	6
trans-1,2-dichloroethene	100	100	10	10
1,2-dichloroethene (total)	---	---	---	55[c]
Methylene chloride (dichloromethane)	5	0	5	5
Nitrobenzene	---	---	---	---
Tetrachloroethene	5	0	5	5
Toluene	1,000	1,000	150	150
1,1,2-trichloroethane	5	3	5	5
Trichloroethene	5	0	5	5
Vinyl chloride	2	0	0.5	0.5

Notes:
[a] Current Drinking Water Standards, Office of Water, 01 July 1999
[b] California Code of Regulations (26 CCR 22-64444), Maximum Contaminant Levels, 1999
[c] United States Environmental protection Agency Preliminary Remediation Goals, Region IX.

Acronyms/Abbreviations:
--- not available
ARAR – applicable or relevant and appropriate requirement
U.S. EPA – United States Environmental Protection Agency

- state primary MCLs for organic compounds in Title 22 *California Code of Regulations* (CCR); and
- Resource Conservation and Recovery Act (RCRA) groundwater protection standards in Title 22 CCR Section 66264.94(a)(1),(a)(3), (c), (d), and (e).

It is not technically or economically feasible to achieve background (i.e., nondetect) levels of VOCs in the contaminant plume as required under the RCRA groundwater protection standards. Therefore, as provided for in 22 CCR 66294.94(c), concentration limits based on MCLs, nonzero MCLGs, and health-based criteria have been set as the remedial goals for Site 70. Numerical values of potential groundwater ARARs and identification of the most stringent criteria are presented in Table B2-3.

The point of compliance for MCLGs and MCLs under the Safe Drinking Water Act (SDWA) is at the tap. For CERCLA remedies, however, U.S. EPA indicates that nonzero MCLGs or MCLs should be attained throughout the contaminated plume, or at and beyond the edge of the waste management area when the waste is left in place *(55 Federal Register* 8753). The CERCLA point of compliance is consistent with that specified under the RCRA groundwater protection standards, which state that the point of compliance at which the protection standards apply is a vertical surface, located at the hydraulically downgradient limit of the waste management area that extends throughout the uppermost aquifer underlying the regulated unit (22 CCR 66264.95) The point of compliance for IR Site 70 will be the NAVWPNSTA Seal Beach site boundary or the existing groundwater point of use, whichever is hydraulically most upgradient.

For IR Site 70, the point of compliance evaluated for shallow groundwater was Monitoring Well (MW)-70-02 (Figure 1-17 in the FS). Monitoring at the MW-70-02 point of compliance would be performed to verify contaminated groundwater is not migrating off-station at unacceptable levels. For intermediate/deep groundwater, the point of compliance evaluated was well NVLW-SB3 (Navy Well No-3, Figure 1-9a).

The California State Water Resources Control Board (SWRCB) Resolution No 68-16 establishes the policy that high-quality waters of the state "shall be maintained to the maximum extent possible" consistent with the "maximum benefit to the people of the state." This has been interpreted by the SWRCB to include a prohibition on the continued migration of existing groundwater contaminant plumes at levels that exceed background for the aquifer (SWRCB 1994). The DON has considered this position, and determined that further migration of already contaminated groundwater is not a discharge governed by the language in SWRCB Resolution No. 63-16. More specifically, the language indicates that it is prospective in intent, applying to new discharges in order to maintain existing high-quality waters. It is not intended to apply to restoration of waters that have already degraded.

Resolution No. 68-16 is an ARAR only for the discharge of treated groundwater that is included in Alternatives 6, 7, 9, and 10 for IR Site 70. It will be discussed in this application in Section R-B4, Action-Specific ARARs.

R-B2.1.2 Surface Water ARARs Conclusions

Surface water discharge is included as a potential remedial action for IR Site 70. Discharge to surface waters must comply with the intent of CERCLA Section 121(d)(2)(B)I and is codified in 40 CFR 131.36 (referred to as the National Toxics Rule [NTR])(57 Federal Register 60848). The federal ambient water quality criteria (FAWQC) contained in the amended NTR are potential applicable federal ARARs for discharges to surface waters. The WQCP for the Santa Ana River Basin (RWQCB 1995) and the ancillary California Ocean Plan (WQOs (SWRCB 1997) are potential state ARARs for discharges to surface waters.

B2.1.3 Air ARARs Conclusions

Air stripping and vapor-phase granular activated carbon (VGAC) are treatment technologies being considered for groundwater. Direct discharge of air stripping tower emissions into the atmosphere must comply with the SCAQMD Rules. SCAQMD Rules 212, 402, 1303, and 1401 are potential ARARs for remedial alternatives being considered under this action. SCAQMD Rules 212 and 1303 are federal ARARs because the U.S. EPA delegated them into the State Implementation Plan (SIP) under the Clean Air Act (CAA), 40 *United States Code* (USC) 7401 et seq. SCAQMD Rules 401 and 1401 are state ARARS because they are not included in the SIP. More specific information on these requirements is provided in the discussion of action-specific ARARs.

B2.1.4 Soil ARARs Conclusions

Except for the no action alternative, all remedial actions being considered for IR Site 70 include construction of monitoring/extraction wells. Federal and state requirements for characterizing wastes will be applicable to the drill cuttings and contaminated personal protective equipment generated from the implementation of the remedial action.

R-B2.2 GROUNDWATER ARARS

The ERSE (BNI 1999) indicated that groundwater beneath IR Site 70 is contaminated with VOCs. Background information on IR Site 70 and the scope of this action are presented in Section R-1 of this RFS.

Potential ARARs for groundwater for this action at IR Site 70 were identified to provide information for decisions regarding cleanup levels for groundwater remediation. Federal and state ARARs for groundwater are discussed in the following sections.

R-B2.2.1 Federal

One of the significant issues in identifying ARARs for groundwater under the SDWA and RCRA is whether the groundwater at the site can be classified as a source of drinking water. U.S. EPA groundwater policy is set forth in the preamble to the NCP *(55 Federal Register 8752-8756)*. This policy uses the groundwater classification system set forth in the draft U.S. EPA Guidelines for Groundwater Classification under the EPA Groundwater Protection Strategy (U.S. EPA 1986). Under this policy, groundwater is classified in one of three categories (Class I, II, or III), based on ecological importance, replaceability, and vulnerability considerations. Irreplaceable groundwater that is currently used by a substantial population or groundwater that supports a vital habitat is considered to be Class I. Class II consists of groundwater that is currently being used or that might be used as a source of drinking water in the future. Groundwater that cannot be used for drinking water due to insufficient quality (e.g., high salinity or widespread, naturally occurring contamination) or quantity is considered to be Class III. The U.S. EPA guidelines define Class III groundwater as groundwater with total dissolved solids (TDS) concentrations over 10,000 milligrams per liter (mg/L).

The aquifer underlying NAVWPNSTA Seal Beach (Orange County Management Zone) is classified as a Class II aquifer and is designated by the RWQCB Santa Ana Region as a potential source of drinking water, along with other beneficial uses such as agricultural and industrial. The evaluation of ARARs for the Site 70 action is based on this determination.

R-B2.2.1.1 SAFE DRINKING WATER ACT

MCLs under the SDWA are potential relevant and appropriate requirements for aquifers with Class I and Class II characteristics, and therefore are potential federal ARARs.

The NCP states that MCLGs that are set at levels above zero should be considered to be relevant and appropriate requirements for groundwaters that are potential sources of drinking water (40 CFR 300.430[e][2][i][B) and 55 *Federal Register 8750-8754)*. Some VOCs of concern at IR Site 70 will have nonzero MCLGs. MCLGs for these chemicals of concern are considered to be relevant and appropriate requirements.

Only the primary MCLs or MCLGs for VOCs (40 CER 141.12) are ARARs for this action. MCLs for inorganic compounds specified in 40 CFR 141.11 are outside the scope of this action. Furthermore, it has been determined that the Station has not contributed to the regional groundwater TDS and nitrate contamination (BNI 1999).

R-B2.2.1.2 RCRA GROUNDWATER PROTECTION STANDARDS

In Title 22 Section 22264.94, the concentration limits for RCRA groundwater protection standards are set for RCRA-regulated units. These regulations state that compounds must not exceed the background level of that constituent in groundwater or, if achieving background is shown to be technologically or economically infeasible, sonic higher concentration limit that is set as part of the corrective action program. In no event shall a concentration limit greater than background exceed MCLs established under the federal SDWA (22 CCR 64435 and 64444).

The RCRA groundwater protection standards are applicable only for regulated units managing hazardous wastes. These standards are not applicable because IR Site 70 does not contain an RCRA waste management unit, and the wastes being addressed by the IR Site 70 actions are not classified as hazardous wastes.

As described in the CERCLA Compliance With Other Laws Manual: Draft Guidance (U.S. EPA 1988b), RCRA requirements may be applicable to CERCLA sites under two scenarios: first, if an RCRA-listed or characteristic hazardous waste is present, and the wastes were managed at the site after the effective date of RCRA; and second, if the CERCLA activity constitutes treatment, storage, or disposal of hazardous waste.

The CERCLA Compliance with Other Laws Manual: Draft Guidance (U.S. EPA 1988b) further states: "......at many Superfund sites no information exists on the source of the wastes. The lead agency should use available site information, manifests, storage records, and vouchers in an effort to ascertain the nature of these contaminants. When this documentation is not available, the lead agency may assume that the wastes are not listed RCRA hazardous wastes. If the lead agency is unable to make an affirmative determination that the wastes are RCRA hazardous wastes, RCRA requirements would not be applicable to CERCLA actions, but may be relevant and appropriate if the CERCLA action involves treatment, storage, or disposal, and if the wastes are similar or identical to RCRA hazardous wastes."

Trichloroethene (TCE) is used in a variety of industrial processes, including metal degreasing and dry cleaning, as an extraction solvent, as a refrigerant and heat-exchange fluid, and in cleaning and drying electronic parts. TCE is the major component of three listed hazardous wastes: F001 (spent halogenated solvents used in degreasing), F002 (spent halogenated solvents), and U228 (commercial chemical product, manufacturing intermediate, or off-specification TCE). To determine whether any of these wastes were generated at the NAVWPNSTA Seal Beach and whether they were disposed of or released on site, the available historic site information, manifests, and storage records were reviewed during the preliminary assessment (PA) (JEG 1994). No documentation on the specific source of the TCE released to groundwater was located. Therefore, the DON has made the determination that the TCE in the groundwater should not be classified as a listed hazardous waste.

The analytical data collected during the ERSE have been evaluated to determine whether there is a potential for classification of extracted groundwater as a D040 RCRA characteristic hazardous waste due to concentrations of TCE.

The toxicity characteristic concentration for TCE is 500 micrograms per liter (μg/L). Based on the ERSE data, this concentration has the potential to be exceeded only at selected on-station wells screened in the shallow groundwater unit. If an extraction well is placed in a location where the groundwater TCE concentration exceeds the toxicity characteristic, that groundwater will be managed as a hazardous waste from the point of extraction to the point where it blends with other groundwater, thereby rendering the TCE concentration less than the toxicity characteristic concentration. For most locations, groundwater TCE concentrations in the shallow aquifer are significantly below the toxicity characteristic concentration. For the portions of the IR Site 70 plume where DNAPL is suspected, solvent concentrations would be expected to exceed the toxicity characteristic concentration. However, substantive provisions of Title 22 CCR Sections 66264.94(a)(1), (a)(3), (c), (d), and (e) are "relevant and appropriate" federal ARARs for the Site 70 action with regard to groundwater because the wastes released into groundwater, in particular TCE, are similar in composition to listed waste.

It is not technically or economically feasible to achieve background (i.e., nondetect) levels of VOCs in the contaminant plume. Therefore, as provided for in 22 CCR 66264.94(c), concentration limits based on MCLs and nonzero MCLGs have been set as the remedial goals for this action.

R-B2.2.1.3 CERCLA ALTERNATIVE CONCENTRATION LEVELS

Under Section 121(d)(2)(B)(ii) of CERCLA, an alternative concentration limit (ACL) using a point of exposure (akin to a point of compliance) beyond the facility boundary can be used where:

- there are known and projected points of entry of such groundwater into surface water;
- there will be no statistically significant increase of hazardous constituents from groundwater in surface water at the point of entry; and
- there are enforceable institutional controls to preclude human exposure at any point between the facility boundary and the point of entry into surface water

There is no known discharge of groundwater to surface water in the vicinity of IR Site 70. Therefore, exposure-based CERCLA ACLs are not considered to be ARARs for this action.

R-B2.2.1.4 CLEAN WATER ACT

On 22 December 1992, U.S. EPA promulgated FAWQC under the authority of Section 303(c)(2)(B) of the federal Clean Water Act (CWA) in order to establish water quality standards required by the CWA where the state of California had failed to do so (referred to as the NTR) (*57 Federal Register* 60848). These standards are discussed in detail in *57 Federal Register* 60920-60921. The NTR was amended on 04 May 1995 (60 *Federal Register* 22228). The NTR, as amended, is codified at 40 CFR 131.36. The FAWQC contained in the amended NTR are potential applicable federal ARARS for discharges to surface water. However, none of the alternatives considered for this action includes surface water discharge.

The applicability of surface water criteria to groundwater is discussed in Section 121(d)(2)(B)(i) of CERCLA, 40 CFR 300.430(e), and the NCP preamble (55 *Federal Register* 8754-8755). FAWQC may be potentially relevant and appropriate for groundwater only in the absence of promulgated MCLs or MCLGs. In such cases, the FAWQC may be adjusted to reflect only drinking water use and used as remediation goals. For this RFS, the preliminary remediation goals for residential drinking water use, calculated for those contaminants that do not have MCLs or MCLGs, have been used as remedial goals satisfying the intent of the NCP preamble.

R-B2.2.2 State

Issues pertinent to identified potential state ARARs for groundwater are discussed in this section.

R-B2.2.2.1 WATER QUALITY OBJECTIVES AND RELATED REQUIREMENTS

WQOs and related requirements are discussed below.

Porter-Cologne Water Quality Control Act

The Porter-Cologne Water Quality Control Act (Porter-Cologne Act) became Division 7 of the California Water Code in 1969. The Porter-Cologne Act established that each regional board formulate and adopt WQCPs for all areas within the region (Section 13240). It also required that each regional board establish WQOs in the WQCPs that will protect the beneficial uses of the water basin (Section 13241). It required that the regional board prescribe waste discharge requirements that implement the WQCP for any discharge of waste to the waters of the state (Section 13263), including discharges into wells (Section 13382). New WQO's defined within amendments to the WQCP (R8-2004-0001) will be established for NAVWPNSTA Seal Beach Site 70.

The DON accepts the substantive provisions of Sections 13241, 13243, 13263(a), 13269, and 13360 of the Porter-Cologne Act enabling legislation as implemented through the beneficial uses, WQOs, waste discharge requirements, and promulgated policies of the WQCP for the Santa Aim River Basin, SWRCB Resolution No. 88-16, SWRCB Resolution No. 88-63, and state primary MCLs as potential ARARs. Where waste discharge requirements are specified in general permits, the substantive requirements in the permits, but not the permits themselves, are potential ARARs.

Comprehensive Water Quality Control Plan for Santa Ana River Basin

The DON accepts the substantive provisions in Chapters 2 through 4 of the WQCP for the Santa Ana River Basin (RWQCB 1995), including beneficial use, newly defined groundwater manangement zones, WQOs, and waste discharge requirements, as potential ARARs. The beneficial uses designated for the Orange County Management Zone aquifer are ARARs for this RFS.

The WQCP for the Santa Ana River Basin was prepared and implemented by the RWQCB Santa Ana Region to protect and enhance the quality of the waters in the Santa Ana Region. This plan establishes location-specific beneficial uses and WQOs for the surface and ground waters of the region and is the basis of the RWQCB Santa Ana Region regulatory programs. The plan includes both numeric and narrative WQOs for specific groundwater subbasins. The WQOs are intended to protect the beneficial uses of the waters of the region and to prevent nuisance.

The most serious water-related problem in the Santa Ana River Basin is water supply (RWQCB 1995, p. 1-10). Therefore, beneficial use and reuse of water are key aspects of the WQCP for the Santa Ana River Basin. NAVWPNSTA Seal Beach is located in the lower Santa Ana River Basin. The subbasin potentially affected by the remedial actions is the Orange County Management Zone. The subbasin has the following beneficial use designations (RWQCB 1995, p 3-28):

- municipal and domestic supply;
- agricultural supply;

- industrial service supply; and
- industrial process supply.

WQOs have been established for the subbasin, The objectives for TDS and nitrates are listed in Table B2-4.

Table B2-4
Selected Water Quality Objectives for the Orange County Management Zone in the NAVWPNSTA Sail Beach Project Area
(units reported in milligrams per liter)

Subbasin	Total Dissolved Solids	Nitrate – N
Santa Ana Pressure	500	3

Source:
RWQBC 1995, p. 4-41

Acronyms/Abbreviations:
NAVWPNSTA – Naval Weapons Station

The first WQCP for the Santa Ana River Basin was prepared in 1974 (RWQCB 1974). The 1974 plan contained WQOs for the Orange County Management Zone. The WQOs were based on existing (1967 to 1970) groundwater quality. The original WQOs represented "the average quality of water in the zones being pumped

That is, the current groundwater quantity and quality data, based on use, were the background data for establishing the numerical value[s]" (RWQCB 1974). The 1974 plan stated, "The physical extent of these groundwater subbasins and the variations in quality within each subbasin strongly suggest an averaging of the quality to allow the establishment of stringent yet effective objectives for these waters" (RWQCB 1974).

Intended implementation of the WQOs included consideration of localized water quality. "The beneficial uses and water quality objectives set forth in this plan apply to general areas. The Regional Board, in setting waste discharge requirements, will consider the particular impact on beneficial uses within the immediate area of influence of the discharge, the existing quality of receiving waters, and the appropriate water quality objective" (RWQCB 1974).

At NAVWPNSTA Seal Beach, current groundwater concentrations of TDS and nitrates, as reflected in monitoring data, exceed the WQOs at some locations. Based on the discussion of variability in water quality throughout the basin from the 1974 plan, this is not surprising. The elevated background concentrations of TDS and nitrates in the NAVWPNSTA Seal Beach project area are not due to NAVWPNSTA Seal Beach activities (BNI 1999). In some of the remedial alternatives considered in this RFS, extracted treated groundwater would be discharged at locations that would not degrade water quality at the discharge locations. Discharge of treated groundwater would not contribute additional solids or nitrates to the basin, and it would be consistent with WQCP for the Santa Ana River Basin and the WQOs, as a reflection of average (not uniform) water quality in the basin. TDS and nitrate concentrations in discharged water must not be markedly different from the concentrations in the receiving water, if the receiving water violates WQOs. The discharged water must comply with SWRCB Resolution No. 68-16 in areas of cleaner groundwater. See Section B4.7.2 for further discussion.

Cleanup to below background water quality conditions is not required by the SWRCB under the Porter-Cologne Act. Section III.F.1 of SWRCB Resolution No. 92-49 provides that regional boards may require cleanup and abatement to "conform to the provisions of Resolution No. 68-16 of the State Water Board, and the Water Quality Control Plans of the State and Regional Water Quality Control Boards, provided that under no circumstances shall these provisions be interpreted to require cleanup and abatement which achieves water quality conditions that are better than background conditions" (SWRCB 1996).

Numeric WQOs have not been established in the WQCP for the Santa Aim River Basin for VOCs. A narrative objective for toxic substances in groundwater states: "All waters of the region shall be maintained free of substances in concentrations which are toxic, or that produce detrimental physiological responses in human, plant, animal, or aquatic life" (RWQCE 1995, p. 4-14).

As discussed above, the remedial action objectives for VOCs in groundwater are the MCLs, which are designed to be protective of human health, and are more stringent than the FAWQC for the contaminants of concern.

State Water Resources Control Board Resolution Nos. 92-49 and 68-16

DON's Position Regarding SWRCB Resolution Nos. 92-49 and 68-16. The DON recognizes that the key substantive requirements of 22 CCR 66264.94 (add the identical requirements of 23 CCR 2550.4 and Section III.G of SWRCB Resolution 92-49) require cleanup to background levels of constituents unless such restoration proves to be technologically or economically infeasible and an alternative cleanup level of constituents will not pose a substantial present or potential hazard to human health or the environment. In addition, the DON recognizes that these provisions are more stringent than corresponding provisions of 40 CER 264.94 and, although they are federally enforceable via the RCRA program authorization, they are also independent[y based on state law to the extent that they are more stringent than the federal regulations.

The DON has also determined that SWRCB Resolution 68-16 is not a chemical-specific ARAR for determining response action goals. However, SWRCB Resolution 68-16 is an action-specific ARAR for regulating discharged treated groundwater back into the aquifer. The DON has determined that further migration of already-contaminated groundwater is not a discharge governed by the language in SWRCB Resolution 68-16.

More specifically, the language of SWRCB Resolution 68-16 indicates that it is prospective in intent applying to new discharges in order to maintain existing high-quality waters. It is not intended to apply to restoration of waters that are already degraded.

The DON's position is that SWRCB Resolutions 92-49 and 68-16 and 23 CCR 2550.4 do not constitute chemical-specific ARARs for this response action because they are state requirements and are not more stringent than federal ARAR provisions of 22 CCR 66264.94. The NCP set forth in 40 CER 300.400(g)(4) provides that only state standards more stringent than federal standards may be ARARs (also see Section 121(d)(2)(A)(ii)) (42 U.S.C. § 9621(d)(2)(A)(ii) of CERCLA).

The substantive technical standard in the equivalent state requirements (i.e., 23 CCR, Division 3, Chapter 15; and SWRCB Resolutions 92-49 and 68-16) is identical to the substantive technical standard in 22 CCR 66264.94. This section of 22 CCR will likely be applied in a manner consistent with equivalent provisions of other regulations, including SWRCB Resolutions 92-49 and 68-16.

State of California's Position Regarding SWRCB Resolution Nos. 92-49 and 68-46. The state does not agree with the DON determination that SWRCB Resolutions 92-49 and **68-16** and certain provisions of 23 CCR, Division 3, Chapter 15 are not ARARS for this response action. SWRCB has interpreted the term "discharges" in the California Water Code to include the movement of waste from soils to groundwater and from contaminated to uncontaminated water (SWRCB 1994). However, the state agrees that the proposed action would comply with SWRCB Resolutions 92-49 and 68-16, and compliance with the 22 CCR provisions should result in compliance with the 23 CCR provisions. The state does not intend to dispute the ROD, but reserves its rights if implementation of the 22 CCR provisions is not as stringent as state implementation of 23 CCR provisions. Because 22 CCR regulation is part of the state's authorized hazardous waste control program, it is also the state's position that 22 CCR 66264.94 is a state ARAR and not a federal ARAR (United States *v.* State of Colorado, 990 F.2d 1565 [1993].

Whereas the DON and the state of California have not agreed on whether SWRCB Resolutions 92-49 and 68-16 and 23 CCR 2550.4 are ARARs for this response action, this groundwater RFS Report for NAVWPNSTA Seal Beach documents both parties' positions on the resolutions, but does not attempt to resolve the issue.

B2.2.2.2 PRIMARY AND SECONDARY STATE MCLS

Primary and secondary state MCLs are set forth in Title 22 CCR, at:

- Section 64444.5 (Primary Standards Organic Chemicals);
- Section 64435 (Primary Standards Inorganic Chemicals and Physical Quality); and
- Section 64473 (Secondary Drinking Water Standards).

The point of compliance for the state MCLs would be the same as for the federal MCLs.

B2.2.2.3 STATE WATER RESOURCES CONTROL BOARD RESOLUTION NO. 88-63

SWRCB Resolution No. 88-63 states that water sources that contain TDS exceeding 3,000 mg/L (or having electrical conductivity of greater than 5,000 micromhos per centimeter) or a yield of less than 200 gallons per day (gpd) are not reasonably expected by the RWQCBs to supply a public water system. The TDS concentration in the Santa Ana Pressure aquifer is generally less than 3,000 mg/L (ENI 1999). Therefore, the Santa Ana Pressure aquifer is a potential source of drinking water.

However, federal aquifer standards as defined in the NCP preamble and the Office of Solid Waste and Emergency Response (OSWER) Directive 9283.1-09 determine that federal MCLs are principal ARARs when a state does not have a U.S. EPA-endorsed Comprehensive State Groundwater Protection Program. The U.S. EPA guidelines stipulate a higher TDS value (up to 10,000 mg/L) and a lower potential yield (150 gpd) for the primary definition of potential drinking water sources. The federal aquifer classification may be more restrictive since it stipulates both TDS level and yield as criteria for aquifer classification. Hence, the federal standards are more restrictive and applicable

R-B2.2.2.4 TITLE 27 CCR, DIVISION 2, SUBDIVISION 1, SECTIONS 20380(A) AND 20400(A), (C), (D), (E), AND (G)

The DON has reviewed the provisions of Title 27 CCR, Division 2, Subdivision 1, Sections 20380(a) and 20400(a), (c), (d), (e), and (g) and determined that they are identical to those found in Title 22 CCR Section 66264.94(d)(1),(2), and (4), and (e)(l) and (2). Also, 23 CCR 20405 is not more stringent than 22 CCR 66264.95. Those requirements of Title 22 are considered to be federal ARARs because they are part of the authorized state program under RCRA.

Because the requirements of Title 27 identified above are not more stringent than the federal ARARs, the Title 27 requirements identified above are not ARARs for this RFS.

R-B2.2.2.5 TITLE 23 CCR, DIVISION 3, CHAPTER 16

Chapter 16 requirements are intended to protect waters of the state from discharges of hazardous substances from underground storage tanks (USTs).

The DON does not consider Chapter 16 requirements to be ARARs for this RFS because:

- source areas such as leaking USTs are not part of IR Site 70; and
- most of the requirements in Chapter 16 are procedural (i.e., permitting, tank testing, notification, reporting, and use of cleanup funds)

B2.2.2.6 STATE ACTION LEVELS

DTSC state action levels (SALs) are TBCs for contaminants of concern in groundwater that have no state MCLs (RWQCB 1994). SALs are nonenforceable, health-based guidance numbers for drinking water. Several of the detected constituents in groundwater do not have state MCLs. Because the NCP states that MCLGs should be considered to be relevant and appropriate for the groundwater in the aquifer, the MCLG instead of the SAL is determined to be the relevant value for determining remedial action objectives for the aquifer. However, because of the policy of Cal-EPA that any public water system not meeting SALs is required to take corrective action, the SAL would be a requirement for the produced water distributed by a water purveyor. The SAL would not constitute an ARAR, however.

B2.2.2.7 GENERAL GROUNDWATER CLEANUP PERMIT

RWQCB Santa Ana Region issued the General Groundwater Cleanup Permit (General Permit; Order No. R8-2002-0007, National Pollutant Discharge Elimination System [NPDES] No. CAG918001, 23 January 2002) for the treatement of groundwater prior to discharge. The Board adopted two amendments to this permit: Order No. R8-2002-0033 (General Waste Discharge requirements for the reinjection/percolation of extracted and treated groundwater resulting from the cleanup of groundwater); and Order No. R8-2003-0085 (correction to the maximum daily effluent concentration limits specified in Order No R8-2002-0007). In previous communications, Department of Navy correspondence 5090 Ser N45S/0224 5 June 2002 to Mr. Gerard J. Thibeault, Executive Officer of the CRWQCB – Santa Ana Region, the Navy contended that a General Groundwater Cleanup Permit (Monitoring and Reporting Program No. R8-2002-0007-002) was not applicable to the Installation Restoration Program (IRP) at Site 70. However, the Navy accepted the substantive requirements in the permit, such as discharge standards, as the ARARs.

B2.3 SURFACE WATER ARARS

Surface water discharge is included as a potential remedial action for IR Site 70. Discharge to surface waters must comply with the intent of CERCLA Section 121(d)(2)(B)i and is codified in 40 CER 131.36 (referred to as the NTR) (57 *Federal Register* 60848). The FAWQC contained in the amended NTR are potential applicable federal ARARs for discharges to surface waters. The WQCP for the Santa Ana River (RWQCB 1995) and the California Ocean Plan (SWRCB 1997) are potential state ARARS for discharges to surface waters.

R-B2.4 AIR ARARS

For this RFS, the chemicals of concern in groundwater are VOCs. Air stripping is one of the treatment technologies being considered for VOC removal in both the shallow groundwater unit and the principal aquifer treatment plants; therefore, there is the potential for VOCs to be released into the air. Particulate matter, carbon monoxide, sulfur dioxide, and nitrogen dioxide are not expected to be released from the groundwater during treatment, so the requirements controlling those releases are not addressed in this ARARs evaluation

ARARs for air are discussed in greater detail under action-specific requirements.

B2.4.1 Federal

The CAA and RCRA air emission requirements are discussed below.

B2.4.1.1 CLEAN AIR ACT

The CAA establishes the National Ambient Air Quality Standards (NAAQS). NAAQS are not enforceable in and of themselves; they are translated into source-specific emissions limitations by the state (U.S. EPA 1990a). Substantive requirements of the SCAQMD rules that have been approved by U.S. EPA as part of the SIP under the CAA are potential federal ARARs for air emissions (CAA Section 110). The SIP includes rules for emissions restrictions for particulates, organic compounds, and hazardous air pollutants, as well as standards of performance for new sources.

SCAQMD Rules 212 and 1303 are federal ARARs because U.S. EPA approved them as components of the SIP under the CAA (40 USC 7401 et seq.).

B2.4.1.2 RCRA AIR EMISSION REQUIREMENTS

RCRA air emissions standards for vents or equipment leaks pertain to equipment that contains or contacts hazardous wastes with organic concentrations of at least 10 percent by weight. Groundwater extracted from extraction wells is not considered to be federal RCRA hazardous waste. Furthermore, the concentration of organic contaminants in the groundwater does not exceed ID percent by weight. Therefore, this requirement is not an ARAR.

B2.4.2 State

RCRA requirements and SCAQMD rules are described below.

B2.4.2.1 RCRA

State RCRA requirements are considered to be potential federal ARARs because they are included in the authorized state RCRA program and are discussed previously under federal ARARs.

B2.4.2.2 SOUTH COAST AIR QUALITY MANAGEMENT DISTRICT

SCAQMD Rules 401 and 1401 are state ARARs because they are not included in the SIP. More specific information on these requirements is provided in the discussion of action-specific ARARs.

R-B2.5 SOIL ARARS

The key threshold question for soil ARARs is whether or not the wastes generated by the IR Site 70 remedial action, primarily soil cuttings from well installations, would be classified as hazardous waste. There are no soil removal (excavation) actions being considered as part of the remediation. The soil cuttings may be classified as a federal hazardous waste as defined by RCRA and the state-authorized program, or as non-RCRA, state-regulated hazardous waste. If the soil is determined to be hazardous waste, then the appropriate requirements will apply. The same classification determination will be made for spent activated carbon.

R-B2.5.1 Federal

As presented in the Section R-2 of this RFS, no documentation of waste-disposal practices exists that would serve to classify or identify the source of the contamination in IR Site 70. The DON has assumed that, for the purposes of this RFS, the wastes are not listed hazardous wastes, unless further information becomes available to change this assumption.

A second part of the hazardous waste determination is whether the soil cuttings or spent activated carbon could potentially be a characteristic hazardous waste. The soil cuttings do not meet the federal or state characteristics for ignitability, corrosivity, or reactivity. If the soil cuttings exceed their respective toxicity characteristic leaching procedure (TCLP) and solubility threshold limit concentration (STLD) limits, the material would then have to be managed according to RCRA hazardous waste management regulations. Waste soils and spent activated carbon will be tested, however, to determine whether they are hazardous wastes.

B2.5.2 State

Some of the soil cuttings and/or the spent activated carbon may not fail the federal hazardous waste testing, but could be classified as a California-regulated non-RCRA hazardous waste. The material would then have to be managed according to California hazardous waste management regulations and disposed of in a Class I landfill. Spent activated carbon that is regenerated off site may also have to be managed according to California hazardous waste management regulations.

R-B3 LOCATION-SPECIFIC ARARS

Potential location-specific ARARs are identified and discussed in this section. The discussions are presented based upon various attributes of the site location, such as within a floodplain. Additional surveys will be performed in connection with the Remedial Design and Remedial Action (RD/RA) to confirm location-specific ARARs where inadequate siting information currently exists, or in the event of changes to planned facility locations.

R-B3.1 FEDERAL

Potential federal location-specific ARARs are summarized in Table R-B3- 1.

Pertinent and substantive provisions of the following potential ARARs were reviewed to determine whether they are potential federal ARARs for the IR Site 70 groundwater RFS:

- Title 22 CCR 66264.18 (a), (b), and (c) (Hazardous Waste Control Act [HWCA])

- 40 CFR Part 6, 6.302 and Appendix A, excluding Sections 6(a)(2), 6(a)(4), and 6(a)(6); Executive Order 11988, Protection of Floodplains; and Executive Order 11990, Protection of Wetlands
- 36 CFR Part 65 (National Archeological and Historical Preservation Act)
- 36 CFR Part 800 (National Historic Preservation Act, Section 106)
- 16 USC Section 1536(a) (Endangered Species Act of 1973)
- 40 CFR 230.10, 231, 231.1, 231.2, 231.7, and 231.8 (Clean Water Act Section 404)
- 50 CFR Section 35.1 et seq. (Wilderness Act)
- 50 CFR Part 27 (National Wildlife Refuge System)
- 16 USC Section 662 (Fish and Wildlife Coordination Act)
- 16 USC 1271 et seq. and Section 7(a) (Wild and Scenic Rivers Act)
- 16 USC Section 307(c) and Section 1456(c); 15 CFR part 930 and Section 723.45 (Coastal Zone Management Act)
- 16 USC 3504 (Coastal Barrier Resource System)
- 16 USC 461-467 (Historic Sites, Buildings, and Antiquities Act)
- 16 USC 403 (Rivers and Harbors Act of 1890)
- 16 USC Section 703 (Migratory Bird Treaty Act of 1972)
- 16 USC Section 1372(2) (Marine Mammal Protection Act)
- 16 USC Section 1801 et seq. (Magnuson Fishery Conservation and Management Act)

Requirements that are determined to be ARARs or TBCs are identified in Table R-B3-1 in the column denoted by the heading ARAR Determination. Determinations of status for location-specific ARARs were generally based upon consultation of maps or lists included in the regulation or prepared by the administering agency. References to the document or agency consulted are provided in the Comments column and in footnotes to the table. Specific issues concerning some of the requirements are discussed in the following sections.

B3.1.1 Floodplains

The requirements of actions taken within a floodplain (40 CFR Part 6[b], 6.302, and Appendix A) address the potential impacts on floodplain beneficial use (flood control, water quality, and habitat) that could be affected by site remediation.

NAVWPNSTA Seal Beach is outside the study area and is designated "Area Not Included." Therefore, the areas are in a location for which flood hazards are undetermined. However, it is noted that areas directly adjacent to NAVWPNSTA Seal Beach IR Site 70 within the Seal Beach city boundary are mapped as "Zone X" – areas lying outside the 500-year floodplain.

R-B3.1.2 Historic and Cultural Resources

The National Historic Preservation Act requires federally funded projects to identify and mitigate impacts of project activities on properties included in or eligible for the National Register of Historic Places.

Table R-B3-1
Potential Federal Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Hazardous Waste Control Act *					
Within 61 meters (200 feet) of a fault displaced in Holocene time.	New treatment, storage, or disposal of hazardous waste prohibited.	RCRA hazardous waste; treatment, storage, or disposal of hazardous waste.	22 CCR 66264.18(a)	Not an ARAR	The nearest active fault with Holocene movement is the Newport-Inglewood Fault, approximately 8 miles southwest of NAVWPNSTA Seal Beach.
Within 100-year floodplain	Facility must be designed, constructed, operated, and maintained to avoid washout.	RCRA hazardous waste; treatment, storage, or disposal of hazardous waste.	22 CCR 66264.18(b)	Not an ARAR	Potential groundwater treatment plant site locations and extraction wells are not within the 100-year floodplain (as defined by FEMA).
Within salt dome formation, underground mine, or cave.	Placement of noncontainerized or bulk liquid hazardous waste prohibited.	RCRA hazardous waste, placement.	22 CCR 66264.18 (c)	Not an ARAR	Based on geologic information presented in ERSE, salt domes, mines, or caves do not exist at or in the vicinity of NAVWPNSTA Seal Beach.
Executive Order 11988, Protection of Floodplains					
Within floodplain.	Actions taken should avoid adverse effects, minimize potential harm, and restore and preserve natural and beneficial values.	Action that will occur in a floodplain (i.e., lowlands) and relatively flat areas adjoining inland and coastal waters and other flood-prone areas.	40 CFR 6, Appendix A; excluding Sections 6(a)(2), 6(a)(4), 6(a)(6); 40 CFR 6.302	Not an ARAR	Although not surveyed, areas directly adjacent to NAVWPNSTA Seal Beach IR Site 70 within the Seal Beach city boundary are mapped as "Zone X" - areas lying outside of the 500-year floodplain. None of the proposed extraction wells or on-site treatment facilities is within the FEMA-delineated floodplain.
National Archeological and Historical Preservation Act					
Within area where action may cause irreparable harm, loss, or destruction of significant artifacts.	Construction on previously undisturbed land would require an archeological survey of the area.	Alteration of terrain that threatens significant scientific, prehistoric, historic, or archeological data.	Substantive requirements of 36 CFR 65, 40 CFR 6.301(3), 16 USC Section 469	ARAR	An archeological survey for NAVWPNSTA Seal Beach indicates the presence of 186 out of the 250 structures surveyed as eligible for contributing to a historic district. Buildings at IR Site 70 are listed.
National Historic Preservation Act, Section 106					
Historic property owned or controlled by federal agency.	Action to preserve historic properties; planning of action to minimize harm to properties listed on or eligible for listing on the National Register of Historic Places.	Property included in or eligible for the National Register of Historic Places.	Substantive requirements of 36 CFR 800, 40 CFR 6.301(b), 16 USC, Section 470	ARAR	An archaeological survey of NAVWPNSTA Seal Beach indicates the presence of 186 out of 250 structures that are eligible as elements contributing to a historic district. Buildings at IR Site 70 are included.

Table R-B3-1 (continued)
Potential Federal Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Endangered Species Act of 1973					
Critical habitat upon which endangered species or threatened species depend.	Action to conserve endangered species or threatened species, including consultation with the Department of the interior.	Determination of effect upon endangered or threatened species or its habitat.	16 USC 1536(a), 50 CFR 402	ARAR	IR Site 70 remedial activities may affect the Seal Beach NWR, which supports special status species or habitat.
Executive Order 11990, Protection of Wetlands					
Wetland.	Action to minimize the destruction, loss, or degradation of wetlands.	Wetland as defined by EO 11990 Section 7.	40 CFR 6, Appendix A; excluding Sections 6(a)(2), 6(a)(4), 6(a)(6); 40 CFR 6.302	TBC	Jurisdictional wetlands at NAVWPNSTA Seal Beach, identified by U.S. Army Corps of Engineers, are in close proximity to the sites. IR Site 70 remedial actions will include measures to prevent or mitigate any expected impacts on wetlands.
Clean Water Act, Section 404					
Wetland.	Action to prohibit discharge of dredged or fill material into wetland without permit.	Wetland as defined by EO 11990 Section 7.	40 CFR 230.10; 40 CFR 231 (231.1, 231.2,231.7, 231.8)	Not an ARAR	Discharge of dredged or fill material to a wetland is not planned as part of the response action.
Wilderness Act					
Wilderness area.	Area must be administered in such a manner as will leave it unimpaired as wilderness and preserve its wilderness character.	Federally owned area designated as wilderness area.	50 CFR 35.1 et seq. 16 USC, Section 1131	Not an ARAR	NAVWPNSTA Seal Beach is not in a federally owned wilderness area.
National Wildlife Refuge System					
Wildlife	Only actions allowed under the provisions of 16 USC Section 668 dd(c) may be undertaken in areas that are part of the NWR System.	Area designated as part of NWR System.	50 CFR 27; 16 USC, Section 668dd	ARAR	NAVWPNSTA Seal Beach includes the Seal Beach NWR and Bolsa Chica Ecological Reserve. NAVWPNSTA Seal Beach is part of the NWR System.
Fish and Wildlife Coordination Act, Section 662					
Area affecting stream or other water body.	Action taken should protect fish or wildlife.	Diversion, channeling, or other activity that modifies a stream or other water body and affects fish or wildlife.	16 USC 662	Not an ARAR	Response actions are not anticipated to modify a stream or other water body.

Table R-B3-1 (continued)
Potential Federal Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Wild and Scenic Rivers Act					
Within area affecting national wild, scenic, or recreational river.	Avoid taking or assisting in action that will have direct adverse effect on scenic river.	Activities that affect or may affect any of the rivers specified in Section 1276.	16 USC 1271 et seq. and Section 7(a), 40 CFR 6.302(e)	Not an ARAR	No wild, scenic, or recreational rivers are at or in the vicinity of NAVWPNSTA Seal Beach.
Coastal Zone Management Act					
Within coastal zone.	Conduct activities in a manner consistent with approved state management programs.	Activities affecting the coastal zone, including lands hereunder and adjacent shore land.	Section 307(c) of 16 USC 1456(c); also see 15 CFR 930 and 923.45	TBC	NAVWPNSTA Seal Beach is within the Coastal Barrier Resource System.
National Recommended Water Quality Criteria - Correction 1999					
Habitat including freshwater and saltwater environments.	Establishes water quality standards for freshwater, saltwater, and human-health criteria.	Discharge potentially affecting water quality.	40 CFR 131 Section 304(a)(1) of the Clean Water Act	TBC	Establishes water quality standards for freshwater and saltwater that are based on current toxicity information. Where discharges occur to freshwater and saltwater, these criteria provide guidance.
Historic Sites, Buildings, and Antiquities Act					
Historic sites.	Avoid undesirable impacts on landmarks.	Areas designated as historic sites.	16 USC 461-467, 40 CFR 6.301(a)	Not an ARAR	See comments under National Historic Preservation Act.
Rivers and Harbors Act of 1890					
Navigable waters.	Requires permits for structures or work in or affecting navigable waters.	Activities affecting navigable waters.	33 USC 403	Not an ARAR	NAVWPNSTA Seal Beach is in the vicinity of navigable waters. However, remedial actions should have no adverse effect on navigable waters.
Migratory Bird Treaty Act of 1972					
Migratory bird area.	Protects almost all species of native birds in the U.S. from unregulated "take" that can include poisoning at hazardous waste sites.	Presence of migratory birds.	16 USC Section 703	TBC	IR Site 70 remedial action addresses contaminated groundwater. Migratory birds are not likely to be exposed to VOC-affected groundwater or affected by remedial activities.
Marine Mammal Protection Act					
Marine mammal area.	Protects any marine mammal in the U.S., except as provided by international treaties from unregulated "take."	Presence of marine mammals.	16 USC 13722)	TBC	The project site is in a coastal zone or area that might be habitat for marine mammals.

Table R-B3-1 (continued)
Potential Federal Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Magnuson Fishery Conservation and Management Act					
Fishery under management.	Provides for conservation and management of specified fisheries within specified fishery conservation zones.	Presence of managed fisheries.	16 USC 1801 et seq.	Not an ARAR	The project site is not near areas of managed fisheries.

Notes:
[a] Statutes and policies and their citations are provided as headings to identify general categories of potential ARARs for the convenience of the reader. Listing the statutes and policies does not indicate the DON accepts the entire statutes or policies as potential ARARs. Specific potential ARARs are addressed in the table below each general heading: only substantive requirements of the specific citations are considered potential ARARs.

Acronyms/Abbreviations:
ARAR – applicable or relevant and appropriate requirement
CCR –*California Code of Regulations*
CFR – *Code of Federal Regulations*
DON – U.S. Department of the Navy
EO – Executive Order
ERSE – Extended Removal Site Evaluation
FEMA – Federal Emergency Management Agency
IR – Installation Restoration
NAVWPNSTA Seal Beach – Naval Weapons Station Seal Beach
NWR – National Wildlife Refuge
RCRA – Resource Conservation and Recovery Act
TBC – to be considered
USC – *United States Code*

The National Archeological and Historical Preservation Act requires federally funded projects to identify and mitigate the impacts of project activities on significant scientific, prehistoric, historic, or archeological data. An archeological survey was conducted for portions of NAVWPNSTA Seal Beach (Ogden 1995). As indicated, a total of 186 of the 250 structures addressed in the survey (including both IR Site 40 and IR Site 70) were eligible for nomination to the National Register of Historic Places as contributing elements to a historic district. Structures included at IR Site 70 were designated.

R-B3.1.3 Critical Habitats and Endangered or Threatened Species

Biological resources and sensitive habitats at NAVWPNSTA Seal Beach were identified through field reconnaissance surveys performed in May 1992 and 1994. Personnel from the California Department of Fish and Game and the U.S. Fish and Wildlife Service were also contacted. Two published databases were consulted: the California Natural Diversity Data Base and the California Wildlife Habitat Relationships System. Based on these surveys, none of the IR Site 70 RFS areas were identified to contain habitat that may support special-status species. However, five species of birds and one species of salt marsh habitat plant (classified as endangered either by federal or state agencies) are known to inhabit NAVWPNSTA Seal Beach (BNI 1999).

No federal- or state-listed species or species proposed as rare, threatened, or endangered are known to live in the immediate project area. The requirements pertaining to biological resources are therefore not ARARs.

B3.2 STATE

Potential state location-specific ARARs are presented in Table R-B3-2. Potential location-specific ARARs identified from the state include the WQCP (RWQCB 1995), the Ocean Plan (SWRCB 1997), the Coastal Act of 1976, and the Endangered Species Act. These have been discussed in Section R-B2.

R-B4 ACTION-SPECIFIC ARARS

State and federal potential action-specific ARARs for IR Site 70 are presented in Tables R-B4-3 and R-B4-4. Potential federal action-specific ARARs for IR Site 70 are evaluated in Table R-B4-3. Potential state action-specific ARARs are evaluated in Table R-B4-4. A discussion of the requirements that have been determined to be pertinent to IR Site 70 action is presented in this section for each alternative considered for detailed evaluation. A discussion of how well each alternative satisfies the requirements that have been determined to be ARARs is provided in Section R-5 of the RFS.

Table R-B3-2
Potential State Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Hazardous California Endangered Species Act					
Habitat	No person shall import, export, take, possess, or less any endangered or threatened species or part or product thereof.		Fish and Game Code Sections 2050-2098	TBC	IR Site 70 remedial actions might affect areas that support California-listed endangered species or habitat. The NAVWPNSTA Seal Beach NWR supports endangered species.
California Coastal Act of 1976 *					
Coastal Zone	Regulates activities associated with development to control direct significant impacts on coastal waters and to protect state and national interests in California coastal resources.		Public Resources Code Sections 30000-30900; 14 CCR 13001-13666.4	TBC	The project site is not in an area governed by this statute.
State Water Resources Control Board and California Regional Water Quality Control Board, Santa Ana Region *					
Describes water basins in Santa Ana Region. Establishes beneficial uses of groundwater and surface water. Establishes water quality objectives, including narrative and numerical standards. Establishes implementation plans to meet water quality objectives and protect beneficial uses, and incorporates statewide water quality control plans and policies.	Public Water System.		Water Quality Control Plan for the Santa Ana Basin (Basin Plan) and amendments including R8-2002-0007, R8-2002-0033, R8-2003-0085, and R8-2004-0001.	ARAR	Substantive provisions in Chapters 2 through 4 of the Basin plan are ARARs. The beneficial uses for the Orange County Management Zone are municipal/domestic use (potential drinking water), agricultural supply, industrial service supply, and industrial process supply. These uses also apply to the shallow groundwater system at NAVWPNSTA Seal Beach.
California Ocean Plan of 1997					
Ocean and Coastal Waters.	Provides for the protection of the quality of the ocean waters for use and enjoyment by the people of the State, requiring the control of discharge of waste into the ocean waters.	Discharge potentially affecting water quality.	California Ocean Plan, SWRCB Resolution No. 97-026	ARAR	The remedial actions to be conducted at IR Site 70 may result in discharge of treated groundwater to surface waters terminating in the ocean.

Table R-B3-2 (continued)
Potential State Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Aquatic Habitat/ Species	Action must be taken if toxic materials are placed where they can enter waters of the State. There can be no release that would have a deleterious effect on species or habitat.		Fish and Game Code 5650(a), (b), and (f)		These code sections prohibit the deposition into state waters of, *inter alia*, petroleum products (Section 5650(a)), factory refuse (Section 5650(b)), and any substance deleterious to fish, plants or birds (Section 5650(f)). These are substantive, promulgated environmental protection requirements. These requirements impose strict criminal liability on violators. (*People v. Chevron Chemical Company (1983) 143 Cal. App. 3d 50)*. This imposition of strict criminal liability imposes a standard that is more stringent than federal law. The extent to which each subdivision of Section 5650 is relevant and appropriate depends on the site characterization. Section 5650 makes it unlawful "to deposit in, permit to pass into, or place where it can pass into the waters of this state," enumerated substances as petroleum products, sawdust, wood shavings, factory refuse, or any other substances or materials that are deleterious to fish, plant life, or bird life.
Wildlife Species	Action must be taken to prohibit the taking of birds and mammals, including the taking by poison		Fish and Game Code Section 3005 (Stats. 1957, c. 456, p. 1353, Section 3005)		This code section prohibits the taking of birds and mammals, including taking by poison. "Take" is defined by Fish and Game Code Section 86 to include killing. "Poison" is not defined in the code. Although there is no state authority on this point, federal law recognizes that poison, such as Strychnine, may effect incidental taking. (*Defenders of Wildlife v. Administrator, Environmental Protection Agency (1989) 882. F. 2d. 1295)*. This code section imposes a substantive, promulgated environmental protection requirement. Because the remediation of this site involves treatment of contaminants, this section appears to be applicable and relevant.
Rare Native Plants	Action must be taken to conserve native plants, there can be no releases and/or actions that would have a deleterious effect on species or habitat		Fish and Game Code Section 1908 (Added by Stats. 1977, c. 1181, p. 3869, Section 8)		Section 1908 imposes a substantive requirement by forbidding any "person" to take rare or endangered native plants. California Code of Regulations Title 14, Section 670.2 provides a listing of the plants of California that have been declared to be Endangered, Threatened or Rare. Fish and Game Code Section 67 provides the definition of "person" as any natural person or partnership, corporation, limited liability company, trust, or other type of association. Whether the federal government or contractors acting on behalf of the federal government would fall within the definition is a potential issue. To the extent that there are rare or endangered plants on site, Section 1908 would be an ARAR

Table R-B3-2 (continued)
Potential State Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Endangered Species	Action must be taken to conserve endangered species, there can be no releases and/or actions that would have a deleterious effect on species or habitat.		Fish and Game Code Section 2080 (Added by Stats. 1984, c. 1240, Section 2).		This section prohibits the take, possession, purchase or sell within the state, any species (including rare native plant species), or any product thereof, that the commission determines to be an endangered or threatened species, or the attempt of any of these acts. This section is applicable and relevant to the extent that there are endangered or threatened species in the area which have the potential of being affected if actions are not taken to conserve the species. This section prohibits releases and/or actions that would have a deleterious effect on species or their habitat. This section and applicable Title 14 regulations should be considered applicable, relevant, and appropriate due to the presence of the California least tern, the peregrine falcon, the California brown pelican, and the double-crested cormorant. California Code of Regulations Title 14 Section 670.2 provides a listing of the plants of California declared to be Endangered, Threatened or Rare. California Code of Regulations Title 145 Section 670.5 provides a listing of Animals of California declared to be endangered or threatened. California Code of Regulations Title 14 Section 783 et. seq., provides the implementation regulations for the California Endangered Species Act.
Wildlife / Domestic Species	Action must be taken to prohibit the use of steel-jawed leghold traps		Fish and Game Code Section 3003.1 (Prop. 4, Section 1 approved Nov. 3, 1998, eff. Nov. 4, 1998)		This section prohibits the use of any body gripping trap and provides that it is unlawful for any person, including an employee of the federal government, to use or authorize the use of such device to capture any game mammal, fur-bearing mammal, non-game mammal, protected mammal, or any dog or cat. This prohibition will not apply in the extraordinary case where the use of such a device is the only method available to protect human health and safety.

Table R-B3-2 (continued)
Potential State Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Fully Protected Bird Species / Habitat	Action must be taken to prevent the taking of fully protected birds		Fish and Game Code Section 3511 (Added by Stats. 1970, c. 1036, p. 1848 Section 4)		This section provides that it is unlawful to take or possess any of the following fully protected birds: a. American peregrine falcon b. Brown pelican c. California black rail d. California clapper rail e. California condor f. California least tern g. Golden eagle h. Greater sandhill crane i. Light footed clapper rail j. Southern bald eagle k. Trumpeter swan l. White-tailed kite m. Yuma clapper rail Although some of the fully protected birds are not typically found in Site 70, this statute will be considered Applicable and Relevant if any of the above mentioned fully protected birds or their habitat are found on or near the site.
Wetlands	Actions must be taken to assure that there is "no net loss" of wetlands acreage or habitat value. Action must be taken to preserve, protect, restore, and enhance California's wetland acreage and habitat values.		Fish and Game Commission Wetlands Policy (adopted 1987) included in Fish and Game Code Addenda		This policy seeks to provide for the protection, preservation, restoration, enhancement, and expansion of wetland habitat in California. Further, it opposes any development or conversion of wetland that would result in a reduction of wetland acreage or habitat value. It adopts the USFWS definition of a wetland which utilizes hydric soils, saturation or inundation, and vegetable criteria, and requires the presence of at least one of these criteria (rather than all three) in order to classify an area as a wetland. This policy is not a regulatory program and should be included as a TBC.

Table R-B3-2 (continued)
Potential State Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Fully Protected Mammals	Action must be taken to ensure that no fully protected mammals are taken or possessed at any time		Fish and Game Code section 4700 (Added by Stats. 1970, c. 1036, p. 1848 Section 6)		This section prohibits the take or possession of any of the fully protected mammals or their parts. The following are fully protected mammals: a. Morro Bay kangaroo rat b. Bighorn sheep except Nelson bighorn sheep c. Northern elephant seal d. Guadalupe fur seal e. Ring-tailed cat f. Pacific right whale g. Salt-marsh harvest mouse h. Southern sea otter i. Wolverine Although some fully protected mammals are not typically found in Site 70, this statute will be considered Applicable and Relevant if any of the above mentioned fully protected mammals or their habitat are found on or near the site.
Fully Protected Reptiles and Amphibians	Actions must be taken to prevent the take or possession of any fully protected reptile or amphibian		Fish and Game Code Section 5050 (Added by Stats. 1970, c. 1036, p. 1849 Section 7)		This section prohibits the take or possession of fully protected reptiles and amphibians or parts thereof. The following are fully protected reptiles and amphibians: a. Blunt-nosed leopard lizard b. San Francisco garter snake c. Santa Cruz long-toed salamander d. Limestone salamander e. Black toad Although some fully protected reptiles and amphibians are not typically found in Site 70, this statute will be considered Applicable and Relevant if any of the above mentioned fully protected reptiles or amphibians or their habitat are found on or near the site.
Birds	Action must be taken to avoid the take or destruction of the nest or eggs of any bird		Fish and Game Code Section 3503		This section prohibits the take, possession, or needless destruction of the nest or eggs of any bird, except as otherwise provided by this code or any regulation made pursuant thereto.

Table R-B3-2 (continued)
Potential State Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Birds of Prey	Action must be taken to prevent the take, possession, or destruction of any birds-of-prey or their eggs		Fish and Game Code Section 3503.5 (Added by Stats. 1985, c. 1334, Section 6)		This section prohibits the take, possession, or destruction of any birds in the orders of Falconifromes or Strigifromes (birds-of-prey) or to take, possess, or destroy the nest or eggs of any such bird except as otherwise provided by this code or any regulation adopted pursuant thereto. This section will be applicable and relevant if such species or their eggs are located on or near the site.
Non-Game Birds	Actions must be taken to prevent the take of non-game birds		Fish and Game Code Section 3800 (Added by Stats. 1971, c. 1470, p. 2906, Section 13)		This section prohibits the take of non-game birds, except in accordance with regulations of the commission, or when related to mining operations with a mitigation plan approved by the department. This section further provides requirements concerning mitigation plans related to mining. This section is applicable and relevant if non-game birds or their eggs are located on or near the site and such species have not been included in the Fish and Wildlife Conservation Plan filed pursuant to the Federal Fish and Wildlife Conservation Act. Species included in the plan will be protected at the federal standard making this section an ARAR to the extent that it is more stringent than the federal standard of protection.
Fur-Bearing Mammals	Provides manners under which fur-bearing mammals may be taken		Fish and Game Code Section 4000 et. Seq. (Stats. 1957, c. 456, p. 1380, Section 4000)		This section provides that a fur-bearing mammal may be taken only with a trap, a firearm, bow and arrow, poison under a proper permit, or with the use of dogs
Non-Game Mammals	Action must be taken to avoid the take or possession of non-game animals		Fish and Game Code Section 4150 (Added by Stats. 1971, c. 1470, p. 2907, Section 21)		Non-game mammals are those occurring naturally in California which are not game mammals, fully protected mammals, or fur-bearing mammals. These mammals, or their parts, may not be taken or possessed except as provided in this code or in accordance with regulations adopted by the commission.

Table R-B3-2 (continued)
Potential State Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Non-Game Animals	Action must be taken to avoid the take of non-game mammals except as provided in applicable regulations		Title 14 California Code of Regulations (CCR) Section 472, Effective 07/01/74		This Regulation provides that non-game birds and mammals may not be taken. a. The following non-game birds and mammals may be taken except as provided in Chapter 6: English sparrow, starling, coyote, weasels, skunks, opossum, moles and rodents (excludes tree and flying squirrels, and those listed as furbearers, endangered, or threatened species); b. Fallow, sambar, sika, and axis deer may be taken concurrently with the general deer season; c. Aoudad, mouflon, tahr, and feral goats may be taken all year; and d. American crows may be taken only under provisions of Section 485 and by landowners or tenants, or person authorized by landowners or tenants, when American crows are committing or about to commit depredations upon ornamental shade trees, agricultural crops, livestock, or wildlife, or when concentrated in such numbers and manner as to constitute a health hazard or other nuisance. If required by Federal regulations, landowners or tenants shall obtain a Federal migratory bird depredation permit before taking any American crows or authorizing any other person to take them. Although some of the non-game birds and mammals are not typically found in Site 70, this statute will be Applicable and Relevant if any of the above mentioned non-game birds and mammals or their habitat are found on or near the site.
Tidal Invertebrates	Action must be taken to avoid the take or possession of mollusks, crustaceans, or other invertebrates		Fish and Game Code Section 8500 (Added by Stats. 1972, c. 1248, p. 2436, Section 2, eff. Dec. 13, 1972)		It is unlawful to possess or take, unless otherwise expressly permitted in this chapter, mollusks, crustaceans, or other invertebrates, unless a valid tidal invertebrate permit has been issued. The taking, possessing, or landing of such invertebrates pursuant to this section shall be subject to regulations adopted by the commission.
Protected Amphibians	Action must be taken to avoid the take or possession of protected amphibians		Title 14 CCR Sections 40 (Section 40 designated effective 03/01/74)		This regulation makes it unlawful to capture, collect, intentionally kill or injure, possess, purchase, propagate, sell, transport, import, or export any native reptile or amphibian, or parts thereof unless under special permit from the department issued pursuant to Title 14 CCR, Sections 650, 670.7, or 783 of these regulations, or as otherwise provided in the Fish and Game Code or these regulations.

Table R-B3-2 (continued)
Potential State Location-Specific ARARs

Location	Requirement	Prerequisite	Citation	ARAR Determination	Comments
Furbearing Mammals	Action must be taken to avoid take		Title 14 CCR, Section 460 (effective 07/01/59)		Regulation makes it unlawful to take fisher, marten, river otter, desert kit fox, and red fox. Although some of the mammals are not typically found in Site 70, to the extent that the red fox, which is highly possible to occur in the area, or its habitat is found on or near Seal Beach NWS, this section will be an ARAR.
Furbearing Mammals	Provides methods of take for other forbearing mammals not listed in Title 14 CCR, Section 460		Title 14 CCR, Section 465 (effective 07/01/69)		Furbearing mammals not listed specifically in Title 14 CCR Section 460 and listed in 14 CCR, Section 461, 462, 463, and Section 464 may be taken only with a firearm, bow and arrow, or with the use of dogs, or traps in accordance with the provisions of Section 465.5 of Title 14 and Section 3003.1 of the Fish and Game Code. Although these mammals may not be currently present in Site 70, if one is found on or near Site 70 at some future date, this section will become applicable and relevant.

Notes:
[a] Statutes and policies and their citations are provided as headings to identify general categories of potential ARARs for the convenience of the reader. Listing the statutes and policies does not indicate the DON accepts the entire statutes or policies as potential ARARs. Specific potential ARARs are addressed in the table below each general heading: only substantive requirements of the specific citations are considered potential ARARs.

Acronyms/Abbreviations:
ARAR – applicable or relevant and appropriate requirement
CCR – *California Code of Regulations*
DON – U.S. Department of the Navy
NAVWPNSTA Seal Beach – Naval Weapons Station Seal Beach
NWR – National Wildlife Refuge
SWRCB – State Water Resources Control Board
TBC – to be considered

Table R-B4-3
Potential Federal Action-Specific ARARs, IR Site 70

Under ARAR Determination, numbers listed under Applicable (A), Relevant and Appropriate (RA) or To Be Considered (TBC) columns correspond to the individual Alternatives as follows: 1 – no action; 6 – hydraulic containment (dissolved plume) and *in situ* treatment (DNAPL area); 7 – hydraulic containment (dissolved plume) and pump and treat (DNAPL area); 9 – pump and treat (dissolved plume) and *in situ* treatment (DNAPL area); 20 – pump and treat (dissolved plume) and pump and treat (DNAPL area); 11– biostimulation combined with bioaugmentation (DNAPL area), bioaugmented biobarriers (dissolved plume).

Action	Requirement	Prerequisite	Citation	ARAR Determination			Comments
				A	RA	TBC	
Safe Drinking Water Act, 42 USC 300f et seq. *							
Underground injection of treated groundwater.	The UIC program regulates the underground injection of fluids under the SDWA to protect sources of drinking water and public health. Five classifications of wells are provided.	Underground injection well.	40 CFR 144, 146, and 147			11	Not an ARAR. Injection of EVO blended with site groundwater and KB-1™ will occur in the source area and biobarriers as part of the Remedial Action.
Resource Conservation and Recovery Act, 42 USC 6901 et seq.							
Waste generation	Generator must determine if waste is an RCRA hazardous waste.	Generation of solid waste, including extracted groundwater.	22 CCR 66262.10(a) and 10(b), 66262.11, 66261.2, 66261.3, 66261.10(a)(1)	6, 7, 9, 10, 11			Applicable for any operation generating waste, including extracted groundwater, soil cuttings from well installation, trench spoils, excavated soils, and treatment residuals such as spent LPC or spent iron. The determination of whether materials are RCRA hazardous will be made at the time wastes are generated.
Hazardous waste accumulation.	Generator may accumulate hazardous waste on site for 90 days or less or must comply with requirements for operating a storage facility.	Generation of hazardous waste.	22 CCR 66262.34				Not an ARAR. No generation or storage of hazardous waste is anticipated as part of this action.
RCRA corrective action.	An area at an RCRA facility may be designated as a CAMU. Placement of remediation wastes (such as excavated soils) into or within a CAMU does not constitute land disposal of hazardous wastes or creation of a unit subject to minimum technology requirements.	RCRA hazardous waste; RCRA CAMU.	40 CFR 264.552				Not an ARAR. No action that would require designation of a CAMU is planned. Excavated soils are not expected to be RCRA hazardous waste.

Table R-B4-3 (continued)
Potential Federal Action-Specific ARARs, IR Site 70

Under ARAR Determination, numbers listed under Applicable (A), Relevant and Appropriate (RA) or To Be Considered (TBC) columns correspond to the individual Alternatives as follows: 1 – no action; 6 – hydraulic containment (dissolved plume) and *in situ* treatment (DNAPL area); 7 – hydraulic containment (dissolved plume) and pump and treat (DNAPL area); 9 – pump and treat (dissolved plume) and *in situ* treatment (DNAPL area); 20 – pump and treat (dissolved plume) and pump and treat (DNAPL area); 11– biostimulation combined with bioaugmentation (DNAPL area), bioaugmented biobarriers (dissolved plume).

Action	Requirement	Prerequisite	Citation	ARAR Determination A	ARAR Determination RA	ARAR Determination TBC	Comments
Placement of waste in land disposal unit.	Must attain land disposal treatment standards before putting RCRA hazardous waste into a permitted disposal Facility.	Placement of RCRA hazardous waste in a landfill, surface impoundment, waste pile, injection well, land treatment facility, salt dome formation, or underground mine or cave.	22 CCR 66268.40				Not an ARAR. In the unlikely event that soil cuttings, trench spoils, and/or excavated soils are determined to be RCRA hazardous waste, these materials would be sent to a permitted off-site facility for treatment in accordance with applicable regulations and facility operating permit.
Use of equipment that contacts hazardous waste with organic concentrations greater than 20 percent by weight.	Air emission standards for process vents or equipment leaks.	Equipment that contains hazardous waste with organic concentrations of at least 10 percent by weight or process vents associated with specified operations that manage hazardous wastes with organic concentrations of at least 10 ppm.	22 CCR 66264.1030 thorugh 1034 (excluding 1030[c], 1033[j], 1034[c][2], 22 CCR 66264.1050 through 1063 (excluding 1050[c], 1050[d], 1057[g][2], 1061[d], 1063[d][3]				Not an ARAR. Excavated soils and extracted groundwater are not expected to be hazardous waste. VOCs in groundwater are significantly less than 10 percent by weight. However, in the case of the DNAPL area, hydraulic containment may result in levels of VOCs approaching 10 percent by weight.
Clean Water Act, 33 USC 1251 et seq.							
Discharge to POTW.	Pretreatment standards to control the introduction of pollutants into POTWs.		40 CFR 403				Not an ARAR. Discharge to a POTW is not planned as part of this action.
Clean Water Act, 40 USC 1313 et seq.							
Discharge to surface waters.	Recommended water quality criteria for freshwater and saltwater bodies and human health where exposure to water is anticipated.	Rational compilation of 157 pollutants for surface water bodies listing toxicity levels for freshwater, saltwater, and human health.	40 CFR 131.304(a), 304(a)(1), 303(c)	6, 7, 9, 10			Discharge to surface water bodies of treated water will not exceed toxicity criteria. No discharge to surface water will occur under Alternative 11.
Clean Water Act, 40 USC 7401 et seq.							

Table R-B4-3 (continued)
Potential Federal Action-Specific ARARs, IR Site 70

Under ARAR Determination, numbers listed under Applicable (A), Relevant and Appropriate (RA) or To Be Considered (TBC) columns correspond to the individual Alternatives as follows: 1 – no action; 6 – hydraulic containment (dissolved plume) and *in situ* treatment (DNAPL area); 7 – hydraulic containment (dissolved plume) and pump and treat (DNAPL area); 9 – pump and treat (dissolved plume) and *in situ* treatment (DNAPL area); 20 – pump and treat (dissolved plume) and pump and treat (DNAPL area); 11– biostimulation combined with bioaugmentation (DNAPL area), bioaugmented biobarriers (dissolved plume).

Action	Requirement	Prerequisite	Citation	ARAR Determination A	ARAR Determination RA	ARAR Determination TBC	Comments
Discharge to air.	Provisions of SIP approved by U.S. EPA under Section 110 of CAA.	Major sources of air pollutants.	40 USC Section 7140; portions of 40 CFR Section 52.220 applicable to SCAQMD	6, 7, 9, 11			Requirements applicable to potential emissions of VOCs from groundwater treatment systems or VOCs extracted with soil gas are discussed as state action-specific ARARs in Sections R-B2.5 and B4.3.2 and on Table R-B4-4. Limited VOC emissions from soil cuttings (e.g., soil off-gas) may be encountered during monitoring/extraction well installation. However, the levels of VOC emissions from soils are expected to be minimal.
Criteria for Classification of Solid Waste Disposal Facilities and Practices, 40 CFR Part 257							
Solid waste disposal.	A facility or practice shall not contaminate an underground drinking water source beyond the solid waste boundary or a court-or state-established alternative.	Solid waste disposal facility and practices, except agricultural wastes, overburden resulting from mining operations, land application of domestic sewage, location and operations of septic tanks, solid or dissolved materials in irrigation return flows, industrial discharges that are point sources subject to permits under CWA, source special nuclear or by-product material as defined by the Atomic Energy Act, hazardous waste disposal facilities that are subject to regulation under RCRA Subtitle C, disposal of solid waste by underground well injection, and municipal solid waste landfill units.	40 CFR 257.3-4 and Appendix I				Not an ARAR. Soil excavation is not anticipated. However, if soil is excavated, the substantive provisions of this regulation are relevant and appropriate to excavated soil, which may be used on site as replacement fill if VOC concentrations are below thresholds that trigger shipment to an off-site landfill.

Table R-B4-3 (continued)
Potential Federal Action-Specific ARARs, IR Site 70

Under ARAR Determination, numbers listed under Applicable (A), Relevant and Appropriate (RA) or To Be Considered (TBC) columns correspond to the individual Alternatives as follows: 1 – no action; 6 – hydraulic containment (dissolved plume) and *in situ* treatment (DNAPL area); 7 – hydraulic containment (dissolved plume) and pump and treat (DNAPL area); 9 – pump and treat (dissolved plume) and *in situ* treatment (DNAPL area); 20 – pump and treat (dissolved plume) and pump and treat (DNAPL area); 11– biostimulation combined with bioaugmentation (DNAPL area), bioaugmented biobarriers (dissolved plume).

Action	Requirement	Prerequisite	Citation	ARAR Determination A	RA	TBC	Comments
Solid waste disposal.	A facility shall not discharge dredged or fill material to waters of the United States in violation of the substantive requirements of CWA Section 404.		40 CFR 257.3-3				Not an ARAR. No discharge of dredged or fill material to water is planned as part of this action.
Discharge of Pollutants to U.S. Waters	A facility or practice shall not cause nonpoint source pollution of waters of the united States that violates substantive requirements of a water quality management plan approved under CWA Section 208.		40 CFR 257.3-3(a)				Not an ARAR. No part of this action is expected to increase nonpoint sources of water pollution.

Notes:
[a] Statutes and policies and their citations are provided as headings to identify general categories of potential ARARs for the convenience of the reader. Listing the statutes and policies does not indicate the DON accepts the entire statutes or policies as potential ARARs. Specific potential ARARs are addressed in the table below each general heading: only substantive requirements of the specific citations are considered potential ARARs.

Acronyms/Abbreviations:
A – applicable
ARAR – applicable or relevant and appropriate requirement
CAA – Clean Air Act
CAMU – corrective action management unit
CCR – *California Code of Regulations*
CFR – *Code of Federal Regulations*
CWA – Clean Water Act
DNAPL – dense nonaqueous-phase liquid
DON – U.S. Department of the Navy
EVO – emulsified vegetable oil

Table R-B4-3 (continued)
Potential Federal Action-Specific ARARs, IR Site 70

IR – Installation Restoration
LPC – liquid-phase carbon
MNA – monitored natural attenuation
NA – Not Applicable
NAVWPNSTA Seal Beach – Naval Weapons Station Seal Beach
POTW – publicly owned treatment works
ppmw – parts per million by weight
RA – relevant and appropriate
RCRA – Resource Conservation and Recovery Act
SCAQMD – South Coast Air Quality Management District
SDWA – Safe Drinking Water Act
SIP – State Implementation Plan
SWRCB – State Water Resources Control Board
TBC – to be considered
UIC – underground injection control
USC – *United States Code*
U.S. EPA – United States Environmental Protection Agency
VOC – volatile organic compound

Table R-B4-4
Potential State Action-Specific ARARs, IR Site 70

Under ARAR Determination, numbers listed under Applicable (A), Relevant and Appropriate (RA) or To Be Considered (TBC) columns correspond to the individual Alternatives as follows: 1 – no action; 6 – hydraulic containment (dissolved plume) and *in situ* treatment (DNAPL area); 7 – hydraulic containment (dissolved plume) and pump and treat (DNAPL area); 9 – pump and treat (dissolved plume) and *in situ* treatment (DNAPL area); 20 – pump and treat (dissolved plume) and pump and treat (DNAPL area); 11– biostimulation combined with bioaugmentation (DNAPL area), bioaugmented biobarriers (dissolved plume).

Action	Requirement	Prerequisite	Citation	ARAR Determination A	RA	TBC	Comments
State Water Resources Control Board and California Regional Water Quality Control Board, Santa Ana Region*							
Actions affecting water quality in the Santa Ana Region	Describes water basins in the Santa Ana Region. Establishes beneficial uses of surface water and groundwater. Establishes water quality objectives, including narrative and numerical standards. Establishes implementation plans to meet water quality objectives and protect beneficial uses, and incorporates statewide water quality control plans and policies.		Water Quality Control Plan for the Santa Ana River Basin (Basin Plan) and amendments including R8-2002-0007, R8-2002-0033, R8-2003-0085, and R8-2004-0001.	6, 7, 9, 10, 11			Substantive provisions in Chapters 2 through 4 of the Basin Plan are ARARs. The beneficial uses of the Orange County Management Zone are municipal and domestic use (potential drinking water), agricultural supply, industrial services supply, and industrial process supply. These uses also apply to the shallow groundwater system at NAVWPNSTA Seal Beach. Protection of these uses is a performance standard for all remedial actions addressing the IR Site 70 plumes.
Discharges to high-quality waters.	Incorporated into Basin Plan. Requires that high-quality waters be maintained unless certain findings are made. Discharges to high-quality waters must comply with antidegradation provisions. At a minimum, beneficial uses must be maintained.	Discharge potentially affecting water quality.	SWRCB Resolution No. 68-16 (Policy With Respect to Maintaining High Quality Waters in California)	6, 7, 9, 10			Action-specific ARAR regulating discharge of treated groundwater by discharge into surface water at NAVWPNSTA Seal Beach. SWRCB Resolution No. 68-16 is only applicable to discharge of treated groundwater, not to the cleanup and/or potential migration of the IR Site 70 plumes.

Table R-B4-4 (continued)
Potential State Action-Specific ARARs, IR Site 70

Under ARAR Determination, numbers listed under Applicable (A), Relevant and Appropriate (RA) or To Be Considered (TBC) columns correspond to the individual Alternatives as follows: 1 – no action; 6 – hydraulic containment (dissolved plume) and *in situ* treatment (DNAPL area); 7 – hydraulic containment (dissolved plume) and pump and treat (DNAPL area); 9 – pump and treat (dissolved plume) and *in situ* treatment (DNAPL area); 20 – pump and treat (dissolved plume) and pump and treat (DNAPL area); 11– biostimulation combined with bioaugmentation (DNAPL area), bioaugmented biobarriers (dissolved plume).

Action	Requirement	Prerequisite	Citation	ARAR Determination A	RA	TBC	Comments
Cleanup and abatement of discharges into the waters of the state.	Incorporated into Basin Plan. Requires cleanup and abatement of discharges into the waters of the state that are consistent with Resolution No. 68-16, beneficial uses of water, and maximum benefit of the people. Establishes procedures for establishing Containment Zones.	Cleanup and discharge of groundwater into the groundwater or surface water and establishment of Containment Zones.	SWRCB Resolution No. 92-49. Policies and procedures for investigation and cleanup and abatement of discharges under Water Code 13304 (as amended on 21 April 1994 and 02 October 1996).			6, 7, 9, 10, 11	Action-specific policy and procedures regulating cleanup, abatement, and discharges to waters of the state. Provides for conformance to Resolution No. 68-16, Chapter 15, maximum benefit to the people of the state, not affecting current or future beneficial uses, and consistent with Basin Plan. Policy and procedures are no more stringent than Basin Plan.
Protection of the quality of the ocean waters for use and enjoyment by the people of the state.	Describes policy for protection of ocean water quality. Includes beneficial use designations, water quality objectives, general requirements, compliance criteria, and discharge prohibitions. All discharges into the ocean must comply with criteria set forth in the Ocean Plan.	Plan is applicable to point source discharges into the ocean and nonpoint sources of waste discharge. Plan provides water quality objectives for receiving waters. Plan does not apply to discharges into enclosed bays and estuaries.	SWRCB Resolution No. 97-026. California Ocean Plan (23 July 1997). Policy set forth in Section 13000 of Division 7 CWC Section 13170 and 13170.2			6, 7, 9, 10	Action-specific policy regulating discharges into the ocean waters of the state. Standards are no more restrictive than the FAWQC.

Table R-B4-4 (continued)
Potential State Action-Specific ARARs, IR Site 70

Under ARAR Determination, numbers listed under Applicable (A), Relevant and Appropriate (RA) or To Be Considered (TBC) columns correspond to the individual Alternatives as follows: 1 – no action; 6 – hydraulic containment (dissolved plume) and *in situ* treatment (DNAPL area); 7 – hydraulic containment (dissolved plume) and pump and treat (DNAPL area); 9 – pump and treat (dissolved plume) and *in situ* treatment (DNAPL area); 20 – pump and treat (dissolved plume) and pump and treat (DNAPL area); 11– biostimulation combined with bioaugmentation (DNAPL area), bioaugmented biobarriers (dissolved plume).

Action	Requirement	Prerequisite	Citation	ARAR Determination A	ARAR Determination RA	ARAR Determination TBC	Comments
Discharges into the waters of the state.	Authorizes the RWQCB to define requirements under which a waste discharge may take place. These are known as Waste Discharge Requirements (WDRs). WDRs establish concentration levels for VOCs and other constituents in treated groundwater. WDRs issued for discharges into surface waters (including storm drains) also require NPDES permit under the federal CWA.		California Water Code, Section 13263; Water Quality Control Plan for the Santa Ana River Basin (Basin Plan.	6, 7, 9, 10, 11			Discharge of treated groundwater may be to surface perimeter storm drain (Alternatives 6, 7, 9, and 10). The off-site discharges into surface water will require NPDES permits. Surface water discharge of treated groundwater,,an on-site response action exempt from permitting under CERCLA, must still comply with the substantive provisions of the Water Code and the Basin Plan. Injection of EVO and KB-1™ blended with site groundwater may require substantive compliance with WDRs.
California Environmental Protection Agency Department of Toxic Substances Control							
Waste generation	Generator must determine if waste is a non-RCRA hazardous waste.	Generation of solid waste in California.	22 CCR 66262.10(a) and 10(b), 66262.11, 66261.2, 66261.3, 66261.101(a) (1) and (1)(2)			6, 7, 9, 10, 11	Applicable for any operation which generates waste. The determination of whether material are non-RCRA hazardous will be made at the time wastes are generated.
California Health and Safety Code							
Waste recycling	Generation, storage, and transportation of hazardous waste for recycling must comply with requirements of 22 CCR 66266. Regeneration of spent GAC may be regulated if this material is a hazardous waste.	Material must be recycled and reused on-site or at another facility owned by the owner of the material.	HSC 25143.2				Not an ARAR, because the spent GAC generated by IR Site 70 remedial actions is not likely to be hazardous. Spent GAC would not be owned by the DON or recycled at a DON facility. It would be managed entirely by a service contractor.

Table R-B4-4 (continued)
Potential State Action-Specific ARARs, IR Site 70

Under ARAR Determination, numbers listed under Applicable (A), Relevant and Appropriate (RA) or To Be Considered (TBC) columns correspond to the individual Alternatives as follows: 1 – no action; 6 – hydraulic containment (dissolved plume) and *in situ* treatment (DNAPL area); 7 – hydraulic containment (dissolved plume) and pump and treat (DNAPL area); 9 – pump and treat (dissolved plume) and *in situ* treatment (DNAPL area); 20 – pump and treat (dissolved plume) and pump and treat (DNAPL area); 11– biostimulation combined with bioaugmentation (DNAPL area), bioaugmented biobarriers (dissolved plume).

Action	Requirement	Prerequisite	Citation	ARAR Determination A	RA	TBC	Comments
South Coast Air Quality Management District							
Discharge into air.	Permits required to construct and operate major new source of air contaminants.	Major source of air pollutants.	SCAQMD Rules 201 and 203			9, 10, 11	Alternatives 9 and 10 have the potential to emit VOCs extracted with groundwater, but off-gassing of groundwater at IR Site 70 is not expected. If off-gassing occurs, the response action will require permitting by the SCAQMD.
Discharge into air.	The discharge of material from any source in quantities that may cause injury, detriment, nuisance, or annoyance to the public is prohibited.	Contamination of air affecting public health and welfare.	SCAQMD Rule 402			9, 10	The vapor control system included with Alternatives 9 and 10 would be designed to prevent nuisance air emissions.
Emissions of halogenated VOCs	All new sources of air pollution that may result in a net emission increase of any non-attainment air contaminant or any halogenated hydrocarbons are to employ BACT.	Net emissions increase of any non-attainment air contaminant or any halogenated hydrocarbons.	SCAQMD Rule 1303			9, 10	Alternatives 9 and 10 have the potential to emit halogenated VOCs. Use of LPC for vapor control would satisfy this ARAR.
Emissions of carcinogenic air contaminants.	T-BACT must be employed for new stationary equipment when the operation of that equipment results in a higher than allowable maximum individual cancer risk.	Stationary source that emits carcinogenic air contaminants.	SCAQMD Rule 1401	9, 10			This is an ARAR because Alternatives 9 and 10 have the potential to emit VOCs that are listed as carcinogenic air contaminants. Use of LPC for vapor control would satisfy this ARAR.

Notes:
[a] Statutes and policies and their citations are provided as headings to identify general categories of potential ARARs for the convenience of the reader. Listing the statutes and policies does not indicate the DON accepts the entire statutes or policies as potential ARARs. Specific potential ARARs are addressed in the table below each general heading: only substantive requirements of the specific citations are considered potential ARARs.

Table R-B4-4 (continued)
Potential State Action-Specific ARARs, IR Site 70

Acronyms/Abbreviations:
- A – applicable
- ARAR – applicable or relevant and appropriate requirement
- BACT – best available control technology
- CCR – *California Code of Regulations*
- CERCLA – Comprehensive Environmental Response, Compensation, and Liability Act
- CWA – Clean Water Act
- CWC – California Water Code
- DNAPL – dense nonaqueous-phase liquid
- DON – U.S. Department of the Navy
- EVO – emulsified vegetable oil
- GAC – granular activated carbon
- HSC – California Health and Safety Code
- IR – Installation Restoration
- NPDES – National Pollutant Discharge Elimination System
- NAVWPNSTA Seal Beach – Naval Weapons Station Seal Beach
- RA – relevant and appropriate
- RCRA – Resource Conservation and Recovery Act
- RWQCB – California Regional Air Quality Management District
- SCAQMD – South Coast Air Quality Management District
- SWRCB – California State Water Resources Control Board
- T-BACT – best available control technology for toxics
- TBC – to be considered
- VOC – volatile organic compound
- WDR – Waste Discharge Requirement

B4.1 IR SITE 40 ALTERNATIVE 1 – NO ACTION

B4.2 IR SITE 40 ALTERNATIVE 2 – MNA

B4.2.1 Federal

B4.2.2 State

B4.2.3 Conclusions

B4.3 IR SITE 40 ALTERNATIVE 3 – HYDRAULIC CONTAINMENT

B4.3.1 Federal

B4.3.2 State

B4.3.3 Conclusions

B4.4 IR SITE 40 ALTERNATIVE 4 – PUMP AND TREAT

B4.4.1 Federal

B4.4.2 State

B4.4.3 Conclusions

B4.5 IR SITE 40 ALTERNATIVE 5 – IN SITU TREATMENT

B4.6 IR SITE 70 ALTERNATIVE 1 – NO ACTION

B4.7 IR SITE 70 ALTERNATIVE 6 – HYDRAULIC CONTAINMENT (DISSOLVED PLUME) AND *IN SITU* TREATMENT (DNAPL AREA)

B4.7.1 Federal

B4.7.2 State

B4.7.3 Conclusions

B4.8 IR SITE 70 ALTERNATIVE 7 – HYDRAULIC CONTAINMENT (DISSOLVED PLUME) AND PUMP AND TREAT (DNAPL AREA)

B4.8.1 Federal

B4.8.2 State

B4.8.3 Conclusions

B4.9 IR SITE 70 ALTERNATIVE 9 – PUMP AND TREAT (DISSOLVED PLUME) AND *IN SITU* TREATMENT (DNAPL AREA)

B4.9.1 Federal

B4.9.2 State

B4.9.3 Conclusions

B4.10 IR SITE 70 ALTERNATIVE 10 – PUMP AND TREAT (DISSOLVED PLUME) AND PUMP AND TREAT (DNAPL AREA)

B4.10.1 Federal

B4.10.2 State

B4.10.3 Conclusions

R-B4.11 IR SITE 70 ALTERNATIVE 11 – BIOSTIMULATION COMBINED WITH BIOAUGMENTATION (DNAPL AREA), BIOAUGMENTED BIOBARRIERS (DISSOLVED PLUME)

R-B4.11.1 Federal

See Section B4.7.1 for a discussion of federal ARARs under CERCLA, RCRA, and SDWA regulations.

R-B4.11.2 State

See Section B4.7.2 for a discussion of state action-specific ARARs from the SWRCB.

South Coast Air Quality Management District

No VOCs should be discharged from the groundwater, EVO, and KB-1™ blending operation because the treatment approach is intended to develop anaerobic condition, and thus groundwater will not be exposed to the atmosphere. Off gassing from soil gas that may be generated from groundwater treatment which migrates into the air may be a TBC under SCAQMD Rules 201, 203, 402, and 1301, and Rule 1401 may become an applicable ARAR for the site.

R-B4.11.3 Conclusions

There is no conflict between the federal and state action-specific ARARs; however, there may be some overlap between federal and state discharge requirements. Both sets of requirements apply to IR Site 70 Alternative 11, as outlined previously.

R-B5 SUMMARY

In this appendix, potential federal and state ARARs have been evaluated for each medium, location, or remedial action addressed in this FS and RFS. The numerical limits chosen as remedial goals for the groundwater remediation have been compared, and the results have been presented in Table B2-3.

The substantive provisions of the following requirements were identified as ARARs that affected the development of remedial action objectives for this action:

- WQCP for the Santa Ana River Basin (RWQCB 1995) (WQOs, beneficial uses, waste discharge limitations);
- Federal MCLs and nonzero MCLGs for VOCs;
- State primary MCLs for VOCs in Title 22 CCR;
- RCRA groundwater protection standards in Title 22 CCR Section 66264 94(a)(1), (a)(3), (c), (d), and (e); and
- SCAQMD Rules 212, 1303, and 1401

As discussed in Section R-B2.1.1 of this appendix and Section R-2 of the RFS report, MCLs and nonzero MCLGs have been identified as the preliminary remedial action cleanup goals for this action because they protect the existing beneficial use of the aquifer and are feasible goals. These goals would apply at the NAVWPNSTA Seal Beach boundary or at the point(s) of existing beneficial use, whichever is hydraulically most upgradient. Cleanup to background level has been determined to be economically and technically infeasible.

The evaluation of location-specific ARARs indicates that the proposed location of the on-station treatment plant or injection station (along with some of the extraction wells and piping) is not within a floodplain.

No historic buildings or landmarks were identified in or near the project area. Phase I archeological surveys will be required for the treatment plant and extraction system locations because much of this area has not been previously surveyed. No requirements relating to biological resources were identified as ARARs.

Actions evaluated as part of the remedial alternatives considered are groundwater extraction, treatment of groundwater by LPC treatment and discharge to surface water bodies; *in situ* chemical oxidation using Fenton's reagent; and enhanced bioremediation through biostimulation and bioaugmentation. RCRA requirements for tank systems may be applicable to some portions of the on-station groundwater extraction and reinjection system because the groundwater at some locations may exceed the TCLP limits for TCE.

Additional information on groundwater concentrations will be obtained during remedial design, and these requirements will be included in the design criteria as necessary.

SCAQMD requirements to be met for emissions from the LPC water treatment system at the on-station treatment facilities include Rules 212, 1303, and 1401. Under the CERCLA exemption for on-site actions, no permit would be required for the discharge from the LPC system; however, all substantive requirements of the SCAQMD requirements would need to be met. Potential air emissions should be minimal from the LPC treatment system. If control of fugitive emissions is required, activated carbon adsorption is considered to be the BACT for treatment systems, and as long as the off-gas control systems are designed to limit the maximum individual cancer risk to less than one in a million, the air strippers should meet these requirements.

SWRCB Resolution No. 68-16 is applicable to discharge of treated groundwater. The VOC treatment systems will be designed to remove VOCs to the detection limit, in order to prevent degradation of groundwater quality at the point of surface discharge. The locations of surface discharge will be chosen to assure that non-VOC components of the treated groundwater (such as TDS and nitrates) will not further degrade the groundwater at the point of surface water discharge. Surface water discharge will result in surface water flow into the Seal Beach NWR and ultimately the ocean. Discharges into the wildlife refuge must meet FAWQC and criteria stipulated in the SWRCB Ocean Plan. Discharges under the Federal Clean Water Act and SWRCB Resolution No. 68-16 fulfill or exceed the stipulations for surface water discharges under the FAWQC and Ocean Plan.

Injection of the EVO, KB-1™, and groundwater blend into the source area and biobarriers will substantively comply with the RWQCB Basin Plan and SWRCB Resolution No. 68-16.

R-B6 REFERENCES

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Department of Toxic Substances Control. 1999a. Letter Request for Identification of Action Specific ARARs, to Interested Parties (Various State and Local Agencies). 13 May.

______ 1999b. Letter Response to Request for Identification of ARARs to SWDIV. June 11.

______ 1999c. Letter Addendum Request for Identification of Chemical- and Location-Specific ARARs, to Various State and Local Agencies. 18 June.

_____ 1999d. Letter Response for Identification of ARARs to SWDTV. 14 July.

DTSC. *See* Department of Toxic Substances Control.

Federal Emergency Management Agency. 1989. Maps for Orange County. September.

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57 Federal Register 60848.

REVISED APPENDIX R-C

DETAILED DESCRIPTION OF PROCESS OPTIONS

FOREWORD

This revised appendix contains a detailed description of the passive biobarrier bioremediation remedial process option considered for the Revised Groundwater Feasibility Study (RFS) Report for Installation Restoration (IR) Site 70 at Naval Weapons Station Seal Beach (NAVWPNSTA Seal Beach), Seal Beach, California. The Table of Contents (TOC) in this Appendix provides a cross reference between Appendix C in the original Feasibility Study (FS; Bechtel 2002) and the revised Appendix C of the RFS. The shaded portions of the TOC reflect elements of Appendix C of the FS that have not been altered for the RFS and are thus incorporated by reference. Unshaded portions of the TOC reflect text that has been added or revised within the RFS.

The information contained herein is referenced primarily in the RFS Section R-3, Identification and Screening of Remedial Technologies. This appendix is organized to follow the order of technologies listed in RFS Table R-3-1 Identification of Remedial Process Options.

The bioremediation technology description contained in this appendix was obtained from GeoSyntec Consultants Inc. (GeoSyntec) project files and the Principles and Practices of Enhanced Anaerobic Bioremediation of Chlorinated Solvents document (ACFEE, 2004). Acknowledgement is given to the Remediation Technologies Development Forum (RTDF) (Ellis *et al.*, 2000) for the case study presented at Dover Air Force Base (AFB) and to the Air Force Center for Environmental Excellence (AFCEE, 2004) for the case study presented at Altus AFB.

Where available, technology descriptions have been supplemented with recent case histories relevant to the RFS Report for IR Site 70 at NAVWPNSTA Seal Beach.

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TABLE OF CONTENTS

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ACRONYMS/ABBREVIATIONS

AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
ARAR	applicable or relevant and appropriate requirement
ASTM	American Society for Testing and Materials
bgs	below ground surface
BMP	Best Management Practice
BTEX	benzene, toluene, ethylbenzene, and xylene
CAH	chlorinated aliphatic hydrocarbon
CBCEC	California Base Closure Environmental Committee
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CES	Current Environmental Solutions
CFR	Code of Federal Regulations
cm/s	centimeters per second
COD	chemical oxygen demand
CROW	contained recovery of oily waste
CSDOC	County Sanitation District of Orange County
DCE	dichloroethene
DNAPL	dense nonaqueous-phase liquid
DOE	Department of Energy
DON	Department of the Navy
DSM	deep soil mixing
DoD	Department of Defense
EBCT	empty bed contact time
ETI	EnviroMetal Technologies, Incorporated
FRTR	Federal Remediation Technologies Roundtable
FS	feasibility study
FY	fiscal year
GAC	granular activated carbon
gpm	gallons per minute

H2O2	hydrogen peroxide
HF	hydraulic fracturing
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HP	horsepower
IDW	investigation-derived waste
INEEL	Idaho National Engineering and Environmental Laboratory
IR	Installation Restoration
ISAS	in situ air stripping
ISEE	in situ steam-enhanced extraction
ISOTEC	In-Situ Oxidative Technologies, Inc.
kg/yr	kilograms per year
kW	kilowatt
LNAPL	light nonaqueous-phase liquid
µg/L	micrograms per liter
MCAF	Marine Corps Air Facility
MCL	maximum contaminant level
mg/L	milligrams per liter
mmHg	millimeters of mercury
MMR	Massachusetts Military Reservation
MSL	mean sea level
NPDES	National Pollutant Discharge Elimination System
NAVWPNSTA	Naval Weapons Station Seal Beach
O3	ozone
O&M	operation and maintenance
OCWD	Orange County Water District
OU	operable unit
PAC	powdered activated carbon
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PF	pneumatic fracturing
POTW	Publicly Owned Treatment Works
ppm	parts per million
PRB	permeable reactive barrier

QA	quality assurance
QC	quality control
RBC	rotating biological contactors
RCRA	Resource Conservation and Recovery Act
RDX	cyclotrimethylenetrinitramine
redox	reduction-oxidation
ROD	record of decision
RTDF	Remediation Technologies Development Forum
scfm	standard cubic feet per minute
SERP	Steam-Enhanced Recovery Process
SITE	Superfund Innovative Technology Evaluation
SIVE	Steam Injection and Vacuum Extraction
STAR	Science, Technology, and Research
SPH	six-phase heating
SVE	soil vapor extraction
SVOC	semivolitile organic compound
TAN	Test Area North
TCA	trichloroethane
TCE	trichloroethene
TCP	trichloropropane
TNT	trinitrotoluene
TPH	total petroleum hydrocarbons
TSD	treatment, storage, and disposal
U.S.EPA	United States Environmental Protection Agency
UV	ultraviolet
VC	vinyl chloride
VEE	vacuum-enhanced extraction
VOC	volatile organic compound
Zimpro	Zimpro Environmental, Inc.

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Revised Appendix R-C

DETAILED DESCRIPTION OF PROCESS OPTIONS

R-C1 ENHANCED BIOREMEDIATION USING BIOAUGMENTED PASSIVE TREATMENT

The following section outlines conditions that enhance microbial activity and expedite natural biodegradation processes to reach cleanup objectives.

R-C1.1 ANAEROBIC BIODEGRADATION

Site-specific conditions may exist where natural degradation processes are limited by nutrients (organic substrates) or by the microbes necessary to degrade the contaminants in the subsurface, typically chlorinated volatile organic compounds (VOCs). The addition of an organic substrate and/or dechlorinating bacterial culture to an aquifer has the potential to further stimulate microbial growth and development, creating an anaerobic environment in which rates of anaerobic biodegradation are enhanced.

R-C1.1.1 Description

Chlorinated hydrocarbons may undergo anaerobic biodegradation under the following mechanisms:

- Reductive Dechlorination – whereby microorganisms in the subsurface gain energy when one or more chlorine atoms on a chlorinated hydrocarbon (electron acceptor) are replaced by hydrogen (electron donor) in an anaerobic environment; and
- Cometabolic Reductive Dechlorination – whereby a chlorinated compound is reduced by a non-specific enzyme or co-factor produced during microbial metabolism of another compound in an anaerobic environment (ACFEE, 2004).

Although one or more of these processes may be operating simultaneously, at many sites, the reductive dehalogenation of chlorinated hydrocarbons appears to be the most important under natural conditions.

Biostimulation

Bioremediation is a process in which indigenous or inoculated microorganisms (i.e., fungi, bacteria, and other microbes) degrade (metabolize) organic contaminants found in soil and/or groundwater. Biostimulation attempts to accelerate the natural biodegradation process by providing nutrients (electron donors) to facilitate rapid conversion of contaminant organics to innocuous end products.

Organic substrates, which act as electron donors and include naturally occurring organic carbon, accidental releases of anthropogenic carbon (i.e., fuel), or introduced substrates such as carbohydrates (i.e., sugars), alcohols, vegetable oils, plant debris (i.e., mulch) and low-molecular-weight fatty acids (i.e., lactate), generate hydrogen by fermentation which is actively consumed by the microorganisms as well as by other bacteria (denitrifiers, iron-reducers, sulfate-reducers, and methanogens). To promote the proliferation of dechlorinating microorganisms, the food source needs to be adequately provided, both for the microorganisms and other species competing for electron donors.

Bioaugmentation

In anaerobic-reducing environments, the main biodegradation mechanism for chlorinated ethenes is reductive dechlorination. In this pathway, the dechlorination of trichloroethene (TCE) proceeds sequentially to the *cis*-isomer (preferentially) of 1,2-dichloroethene (*cis*-DCE), and then to vinyl chloride (VC), followed by ethene.

Sulfate-reducers and methanogens appear to possess the ability to mediate the initial steps of dechlorination of tetrachloroethene (PCE) and TCE to *cis*-DCE. However, specific dehalo-respiring microorganisms (that use chlorinated chemicals as their terminal electron acceptors, instead of oxygen) appear to be required to mediate further and complete dechlorination of *cis*-DCE to VC and ethene (Maymo-Gatell et al., 1997). A number of distinct types of dehalo-respiring bacteria have been identified, including *Dehalospirillium multivorans* (Scholz-Muramatsu et al., 1995), *Dehalobacter restrictus* (Schumacher and Holliger, 1996) and *Dehalococcoides (Dhc) ethenogenes* (Maymo-Gatell et al., 1997). However, to date only *Dehalococcoides ethenogenes* has been demonstrated to complete dechlorination beyond *cis*-DCE to ethene.

A microcosm study may be conducted to determine the presence of dehalo-respiring microorganisms. A microbial analysis is also available that utilizes a DNA polymerase chain reaction (PCR) technique, which identifies the presence or absence of the microbial species based upon the presence of specific DNA sequences that are unique to *Dehalococcoides*-like organisms. Where the dehalorespiring microorganisms necessary for complete degradation to ethene are not present in the subsurface, bioaugmentation may be required. Bioaugmentation is the process of injecting these consortia of dehalorespiring microorganisms into the treatment zone.

Passive Bioremediation

Vegetable oils, due to their limited solubility and immiscible nature, provide a long-lasting, stationary source of organic carbon. Emplacement of vegetable oils in the subsurface can provide a sustained source of organic carbon for stimulation of bioactivity over anticipated lifespans of 1 to 5 years, depending on the groundwater velocity and contaminant mass flux. Permeable barriers may be formed through the injection of vegetable oils into the subsurface to provide passive groundwater treatment, with operational requirements limited to performance monitoring and occasional reinjections (if required).

Once injected, the oil slowly dissolves, generating volatile fatty acids (VFAs), alcohols, and other carbon-based byproducts providing a long-term source of electron donor in the form of dissolved carbon. The electron donor and chlorinated VOCs become mixed when impacted groundwater flows through the zone of injected oil.

The volume of oil required at each injection point must be sufficient to:

a) Provide electron donor in the correct stoichiometric amounts for the chlorinated VOC degradation reactions and overcome competing reactions; and

b) Account for the constant renewal of chlorinated VOCs and other electron acceptors by groundwater flow into the zone of injected oil.

The most common form of the vegetable oil application is the use of an oil-in-water emulsion. Injection of water with the oil acts as a driving force that pushes the oil out into the formation. Modifying the oil saturation in the emulsion (typically 0.5 to 10 percent) is an effective method to control the substrate loading. Oil saturations greater than 10 to 15 percent may cause a reduction in hydraulic conductivity, limit the radius of distribution of the oil around the injection point, and be difficult to inject under high backpressures. Substrate loading can also be controlled by the substrate chosen, as different oils have different degradation rates (Borden, 2002).

Emulsification agents can be used to stabilize the oil emulsion to further extend the zone of electron donor. The agent is usually a long molecule with a hydrophilic (water-soluble) end and a hydrophobic (oil-soluble) end. The agent preferentially forms a coating or skin around the outside of the oil droplet and when sufficient concentrations of emulsification agent are present, the integrity of the droplet is maintained by the skin of the emulsification agent. When the emulsion is introduced to the groundwater, the emulsification agent will partition into the water, as it is weakly soluble in water alone, and the emulsion will "break". At this point, the oil droplet will stop acting as a colloid and begin to act as a hydrophobic droplet that will preferentially sorb to the soil. Once sorbed to the soil, the oil droplet will remain stationary and not flow with groundwater.

The sorbed oil will create a "source" zone of oil in the subsurface. As groundwater flows past the oil droplets, the groundwater will become charged with dissolved vegetable oil, becoming the source of carbon (electron donor) that supports microbial growth for degradation of chlorinated molecules in the groundwater.

R-C1.1.2 Applicability

Oil systems have been used in source areas and biobarrier configurations, with effective remediation of dense, non-aqueous-phase liquid (DNAPL) as well as high and low levels of dissolved-phase chlorinated VOC contamination in groundwater (ACFEE, 2004).

The technology is particularly applicable to situations where conditions are conducive to anaerobic biodegradation but the system is lacking in organic carbon. Biodegradation of an organic substrate (electron donor) depletes the aquifer of dissolved oxygen (DO) and other terminal electron acceptors, which reduces the oxidation-reduction potential (ORP) of groundwater, thereby stimulating conditions conducive to anaerobic degradation processes. After DO is consumed, anaerobic microorganisms typically use native electron acceptors (as available) in the following order of preference: nitrate, manganese and ferric iron oxyhydroxides, sulfate, and finally carbon dioxide. Anaerobic dechlorination has been demonstrated under nitrate, iron, and sulfate reducing conditions, but the most rapid biodegradation rates, affecting the widest range of chlorinated VOCs, occur under methanogenic conditions (Bouwer, 1994).

R-C1.1.3 Advantages

In situ anaerobic bioremediation with oil is advantageous because:

- It has lower capital and maintenance costs (oil emulsion substrate addition can be accomplished using conventional well installations or direct-push technology and the slow release of the substrate allows for limited operational expenditures);
- The contaminants are degraded *in situ*, rather than transferred to another phase where secondary waste treatment is necessary and potential exposure to the contaminants can occur;
- Interphase mass transfer effects from the anaerobic process may increase the rate of DNAPL source zone dissolution, which is potentially applicable where remediation of contaminant source areas has been limited by dissolution;
- It treats a wide variety of contaminants, enabling this form of remediation to be applied to sites where multiple contaminants are present; and
- This technology is easily used in conjunction with other remedial techniques and is directly compatible with monitored natural attenuation.

R-C1.1.4 Limitations

Limitations of oil emulsions and *in situ* anaerobic bioremediation are:

- Balancing the amount of electron donor (oil emulsion) to electron acceptors in the groundwater is difficult with a one-time application. This can result in the excess production of methane that can block pore spaces, or create strongly anaerobic and reducing conditions that may mobilize some indigenous metals (e.g., iron, manganese, and potentially arsenic), cause the transient formation of undesirable fermentation products (e.g., aldehydes and ketones) and produce hydrogen sulfide. Other potential impacts such as changes in the total dissolved solids (TDS) may occur. These secondary water quality impacts may attenuate naturally, provided there is a sufficiently large attenuation zone;
- Degradation can be limited by high levels or influx of competing electron acceptors, and geochemical conditions such as high or low pH can inhibit microbial growth;
- A low permeability or high degree of heterogeneity in the subsurface may limit the ability to effectively distribute the substrate throughout the aquifer; and
- The timeframe to grow a microbial population capable of complete degradation may be on the order of several months to years at many sites, which may require prolonged process monitoring.

Many of these limitations can be abated by an understanding of the conditions of the subsurface and applying appropriate adjustments to the design of the oil system.

R-C1.1.5 Data Needs

Characteristics that should be investigated prior to system design include aquifer permeability, site hydrology, depth, type, concentration and biodegradability of contaminants as well as the parameters listed below. It is advisable that a microcosm study and pilot-scale test be conducted prior to full-scale implementation to assess the feasibility of this remedial approach.

The following parameters should be analyzed prior to system implementation as well as monitored during remedial operations:

- Redox Parameters – factors such as DO and ORP should be monitored to assess changes in redox conditions required in the subsurface to establish anaerobic conditions and ensure a secure environment for microbial growth;
- Metals and Anions – samples for metals and anion analysis should be collected to identify potential competing electron acceptors (e.g., sulfate), determine if metals have been mobilized by changes in redox conditions, and to assess potential issues with secondary water quality parameters;
- Methane – methane production is anticipated in an anaerobic environment and should be monitored to ensure it does not inhibit other biodegradation activities or constitute a health and safety hazard;
- pH – the pH should be monitored to assess if any significant changes in geochemical conditions have occurred. Optimal pH for dechlorination of chlorinated ethenes is in the range of 6 to 8; groundwater pH outside of this range may inhibit bioactivity rates;
- Tracers – the use of tracer compounds, such as bromide, are useful to gauge maximum oil distribution during the implementation of an oil biobarrier and to compare changes in chlorinated VOC concentrations to tracer mass balances for an evaluation of mass loss of these target constituents over time;
- Groundwater Parameters – factors such as temperature, specific conductivity, turbidity, odor and depth to water should be monitored for changes in geochemical conditions;
- Microbial Analysis – an analysis of *Dehalococcoides ethenogenes* prior to and after the oil injection is useful to determine if a sufficient and appropriate microbial population is present in the subsurface for degradation as well as to correlate an increase in the microbial population to the degradation of chlorinated VOCs; and
- VFAs and Total Organic Carbon (TOC) – These parameters should be analyzed to monitor the degradation of electron donor for indication of biological activity and depletion of the electron donor.

R-C1.1.6 Performance Data

Case studies from Dover Air Force Base, Kelly Air Force Base, Launch Complex 34 at the Kennedy Space Center, and Altus Air Force Base demonstrating bioaugmentation, biostimulation using oil emulsions and bioremediation of DNAPL source areas are presented below.

Dover Air Force Base, Dover Delaware

The Remediation Technologies Development Forum (RTDF), a collaboration between federal and industrial partners (www.rtdf.org), evaluated accelerated anaerobic bioremediation and natural attenuation of TCE in groundwater at Dover Air Force Base (AFB) in Delaware. The RTDF constructed more than 1000 microcosms (Lee *et al.*, 2000) using site soil and groundwater amended with various electron donors including: volatile fatty acids (acetate, lactate), alcohols, sugars (including molasses), and complex organics. Although TCE was reduced to *cis*-DCE regardless of the amendment used, conversion past *cis*-DCE to VC and ethene were observed in only a small percentage of microcosms incubated during the course of these studies (up to 500 days), even when methanogenesis was occurring. This result showed that *Dhc* is sparsely distributed at this site because TCE should have been dechlorinated beyond *cis*-DCE in a greater percentage of these microcosms. Thus, we can conclude that microorganisms capable of converting *cis*-DCE to ethene were either absent, very sparsely distributed, or inactive at this site.

Harkness *et al.*, (1999) demonstrated the need for bioaugmentation using columns filled with soil from the Dover AFB site. TCE was not degraded beyond *cis*-DCE in columns that had been fed only electron donors for up to 200 days. This timeframe should have been sufficient to stimulate the growth and activity of any indigenous *Dhc*. Injection of a small volume of a culture containing *Dhc* (the Pinellas culture) into one of the columns stimulated complete dechlorination of *cis*-DCE to ethene within 20 days in that column. The same effect was later observed in a second column injected with the same culture. VC production was transient in both bioaugmented columns, with rapid conversion to ethene. This supports the conclusion that *Dhc* microorganisms were not initially present in the aquifer material but were responsible for complete dechlorination after their addition.

This conclusion was supported by the results of a field bioaugmentation demonstration at the site (Ellis *et al.*, 2000). The pilot treatment area was fed lactate for 269 days, during which time TCE was stoichiometrically dechlorinated to *cis*-DCE. VC and ethene were not produced during this interval. Only after the aquifer was amended with the same culture used in the column studies was *cis*-DCE completely reduced to ethene (Ellis *et al.*, 2000). This result demonstrates the value of bioaugmentation when evidence clearly indicates the absence of organisms capable of complete conversion of *cis*-DCE to ethene. Follow-on analysis using molecular probes (Hendrickson *et al.*, 2002) demonstrated that the *Dhc* present in the culture used for inoculation was detected only within, and not outside of, the pilot test area (PTA), again indicating the need for, and success of, bioaugmentation. Additional sampling performed 2 and 3 years after the completion of the pilot test detected the continued presence of *Dhc ethenogenes*-like bacteria within the PTA, but again not in the upgradient background wells. These data indicate that the *Dhc* strains injected into the subsurface can survive for long periods, and continue to dechlorinate as long as an anaerobic environment is maintained.

Kelly Air Force Base, San Antonio, Texas

Major *et al.* (2002) conducted a demonstration of bioaugmentation for treating dissolved-phase PCE, TCE, and *cis*-DCE at Kelly AFB in San Antonio, Texas. Prior to the demonstration, the site groundwater contained about 1 mg/L of PCE and lower amounts of TCE and *cis*-DCE, without any detectable VC or ethene. Analysis with 16S rDNA-based PCR methods did not detect *Dhc* in any groundwater or sediment samples from the PTA. Laboratory microcosm studies showed that non-bioaugmented treatments containing lactate or methanol resulted in stoichiometric conversion of TCE and *cis*-DCE, without further dechlorination of *cis*-DCE to VC or ethene. Microcosms bioaugmented with KB-1™ (mixed dechlorinating culture) and methanol stoichiometrically converted all of the TCE to ethene.

The field test consisted of three recirculation plots, two that served as control plots, and one that was bioaugmented with KB-1™. The test plot was recirculated for 89 days to equilibrate the system and to conduct the bromide tracer test. From day 90 to day 175, methanol and acetate were added as electron donors to establish reduced conditions and to stimulate reductive dechlorination by the indigenous bacteria. Bioaugmentation with 13L of KB-1™ occurred on day 176. Performance monitoring of the control and test plots showed that in the presence of methanol and acetate, the indigenous bacteria could be stimulated to dechlorinate PCE to *cis*-DCE. However, no dechlorination past *cis*-DCE was observed in the control plots for the remainder of the test. In contrast, VC was detected 52 days after bioaugmentation with KB-1™ in the test plot, and by day 318 ethene was the dominant product. Calculated half-lives for degradation were on the order of minutes to hours. 16S rDNA-based PCR methods were used to monitor the migration and growth of KB-1™ culture after injection. Molecular monitoring showed that the culture had completely colonized the 9.1 meter-long aquifer test plot within 115 days after the one-time injection of KB-1 ™. The two control plots were installed and operated in the same manner as the test plot, but were never amended with KB-1 ™. In these control plots dechlorination stalled at *cis*-DCE, with no VC observed during 216 days of operation. Molecular analysis confirmed that *Dhc* was not present in the control plots.

The most conclusive evidence for the need for bioaugmentation at this site was obtained from molecular techniques, which showed that the "fingerprint" of the *Dhc* species in the KB-1™ culture had spread throughout the bioaugmented test plot, whereas *Dhc* was not detected in the control plots or outside of the bioaugmented test plot. This study also showed that there were naturally-occurring *Dhc* organisms present at a geographically-isolated area of Kelly AFB. Interestingly, these *Dhc* were located in a waste pit that was very clayey, with little to no groundwater movement, and that had received organic waste and chlorinated solvents for decades. This *Dhc* had a different "fingerprint" than the KB-1™ bioaugmentation culture, and this different signature was not detected in the field pilot plot that was bioaugmented.

Launch Complex 34, Kennedy Space Center, FL

Launch Complex 34 (LC-34) is the site of historic releases of TCE, which is present in the subsurface as DNAPL. Up to 40,000 kg of TCE is present in the aquifer below LC34, suggesting that the restoration of groundwater quality through intrinsic remediation processes will require many decades. As part of an ongoing effort to accelerate remediation at LC34, the NASA Small Business Innovation Research (SBIR) program supported a demonstration of enhanced *in situ* bioremediation of TCE DNAPL that was initiated in May 2002. Concurrent performance monitoring for the purpose of technology validation was completed by the USEPA SITE program.

Under intrinsic conditions at LC-34, TCE biodegradation results in the accumulation of *cis*-DCE with limited conversion to VC, suggesting that complete degradation is limited by the absence of the appropriate dehalorespiring microorganisms. Molecular characterization of 16S rRNA sequences of the *Dhc* microorganisms in groundwater at the facility suggest that these organisms are members of the Cornell sequence subgroup, which are loosely defined as a phenotype which is not capable of complete conversion to ethene.

Beginning in October 2002, groundwater amended with a dilute solution of ethanol was recirculated through a test plot constructed within the DNAPL source area. Prior to ethanol amendment, the concentration of TCE in the recirculated groundwater was 160 mg/L. The addition of this electron donor, at a concentration equivalent to a four-fold stoichiometric excess to that required to reduce all electron acceptor in groundwater (primarily TCE and sulfate), resulted in an increase in TCE biodegradation and significant accumulation of *cis*-DCE and VC. Electron donor addition and groundwater recirculation was continued until February 2003 (107 days). Subsequently, the test plot was bioaugmented with 40 L of KB-1™. After a five month lag period, a rapid increase in dechlorination rates was observed with ethene concentrations in a stoichiometric excess of initial TCE concentrations at some sampling locations, suggesting that biodegradation resulted in enhanced dissolution of TCE DNAPL at the local-scale (GeoSyntec, 2003). Further performance monitoring conducted by the USEPA SITE program indicated greater than 98% removal of the DNAPL mass within the treatment area (Battelle, 2004).

This study confirms earlier laboratory evidence indicating the dechlorinating activity is not inhibited by the high VOC concentrations typically associated with TCE DNAPL source zones. The occurrence of high VOC biodegradation rates with complete conversion to ethene, coupled with the absence of significant methanogenesis, suggests that bioaugmentation may be an effective approach for both enhanced DNAPL removal and/or biocontainment of VOC-impacted groundwater in DNAPL source zones.

Altus Air Force Base, Altus, Oklahoma

A field pilot study, sponsored by the Air Force Center for Environmental Excellence (AFCEE), was conducted at Altus AFB in Altus, Oklahoma to evaluate the use of emulsified oil for stimulating *in situ* anaerobic bioremediation of chlorinated solvents. Historical solvent releases of degreasing agents at Altus AFB resulted in a 5,000 ft long chlorinated solvent plume with TCE concentrations reaching 78,000 $\mu g/L$ in the source area.

The pilot test was conducted in an area approximately 250 ft downgradient from the source area. A mixture of emulsified soybean oil, lactate, and yeast extract was injected in a line of six permanent 2-inch polyvinyl chloride (PVC) wells spaced 5 ft apart and installed perpendicular to groundwater flow to create a 30 ft wide Edible Oil Substrate (EOS™) permeable reactive barrier that would stimulate reductive dechlorination. Following injection of the emulsion, water was injected to help distribute the emulsion through the subsurface.

Evidence of the distribution and degradation of the emulsified oil was tracked by monitoring TOC levels. Immediately after the injection, elevated TOC levels above baseline were evident in injection wells and downgradient monitoring points; however locations with low permeabilities showed little to no change in their TOC levels, demonstrating the relevance of permeability on the emulsion distribution.

The injection of emulsified oil was shown to effectively stimulate reductive dechlorination and diminish concentrations of VOCs in the subsurface. Concentrations of total ethenes initially decreased, likely due to dilution and/or sorption to the oil; however, over the long term (7-1/2 months), the concentration of total ethenes was more than 90 percent of the pre-injection TCE concentration, demonstrating that dilution/sorption was no longer significant and that the observed reductions in contaminant concentrations were due to biodegradation. Decreases in TCE and *cis*-DCE and concomitant increases in VC and ethene concentrations further support the degradation of parent products. The degree of biodegradation is dependent on the distribution of emulsion in the aquifer, which is dependent on the aquifer permeability. In locations of higher permeability where fluids would preferentially flow, a substantial increase in reductive dechlorination processes was observed. In areas with low permeability which would restrict fluid flow, no significant enhancement of reductive dechlorination was found (ACFEE, 2004).

Various parameters were tracked to assess the influence the oil emulsion had on the subsurface. Dissolved oxygen, used by microbes as an electron acceptor for the biodegradation of organic carbon, was depleted as aerobic microbes metabolized the oil, creating anaerobic conditions favorable to enhanced reductive dechlorination. In addition, the presence of methane above background conditions indicated microbial degradation (methanogenesis) was occurring and conditions that are conducive for reductive dechlorination. Substantial amounts of dissolved and solid-phase sulfate are present at Altus AFB, which can inhibit reductive dechlorination processes by competing for available hydrogen or producing toxic levels of sulfides. Pre- and post-injection sulfate data illustrated that areas impacted by the emulsion (increased TOC) had corresponding decreases in both sulfate and VOCs, with no inhibition of reductive dechlorination processes (ACFEE, 2004).

The addition of slowly biodegradable organic carbon in the form of a soybean oil-in-water emulsion was found to enhance reductive dechlorination. Biological enhancement is dependent on the distribution of emulsion in the aquifer. Where contaminated groundwater came immediately in contact with the soybean oil emulsion, a substantial increase in reductive dechlorination processes was observed. In these locations, VOC concentrations were shown to generally decline along with dissolved oxygen and sulfate and areas where this was observed showed a significant correlation to the TOC concentrations, providing strong evidence for significant reductive dechlorination.

R-C1.1.7 Costs

The major costs incurred through the use of oil emulsion permeable biobarriers include capital costs for well installation for the oil injections and the oil itself. Typical costs for a 48% emulsion of soybean oil mixed with water, lactate and emulsions (as supplied by RNAS) is around $2.65/kg of emulsion. Operation and maintenance costs consist primarily of electron donor (periodic reinjections of oil emulsion) and monitoring. Little of the capital cost is associated with equipment or instrumentation as no permanent infrastructure is required for the injections. Oil and well installation costs can be minimized by optimizing the spacing between linear barriers to allow for sufficient pore volumes of groundwater to be flushed through the barrier within the targeted remediation timeframe.

R-C1.1.8 References

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REVISED APPENDIX R-D

COST DEVELOPMENT SUMMARIES

FOREWORD

This revised appendix documents the development of order-of-magnitude cost estimates for the bioremediation remedial alternative evaluated in this revised feasibility study (RFS), which addresses groundwater contamination at Installation Restoration (IR) Program Site 70 at Naval Weapons Station Seal Beach (NAVWPNSTA Seal Beach), Seal Beach, California. The Table of Contents (TOC) in this Appendix provides a cross reference between Appendix D in the original Feasibility Study (FS; BNI, 2002) and the revised Appendix R-D of the RFS. The shaded portions of the TOC reflect elements of Appendix D of the FS that have not been altered for the RFS and are thus incorporated by reference. Unshaded portions of the TOC reflect text that has been added or revised within the RFS.

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TABLE OF CONTENTS

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ACRONYMS/ABBREVIATIONS

AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
ARAR	applicable or relevant and appropriate requirement
ASTM	American Society for Testing and Materials
bgs	below ground surface
BMP	Best Management Practice
BTEX	benzene, toluene, ethylbenzene, and xylene
CAH	chlorinated aliphatic hydrocarbon
CBCEC	California Base Closure Environmental Committee
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CES	Current Environmental Solutions
CFR	Code of Federal Regulations
cm/s	centimeters per second
COD	chemical oxygen demand
CROW	contained recovery of oily waste
CSDOC	County Sanitation District of Orange County
DCE	dichloroethene
DNAPL	dense nonaqueous-phase liquid
DOE	Department of Energy
DON	Department of the Navy
DSM	deep soil mixing
DoD	Department of Defense
EBCT	empty bed contact time
ETI	EnviroMetal Technologies, Incorporated
FRTR	Federal Remediation Technologies Roundtable
FS	feasibility study
FY	fiscal year
GAC	granular activated carbon
gpm	gallons per minute

H2O2	hydrogen peroxide
HF	hydraulic fracturing
HMX	octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine
HP	horsepower
IDW	investigation-derived waste
INEEL	Idaho National Engineering and Environmental Laboratory
IR	Installation Restoration
ISAS	in situ air stripping
ISEE	in situ steam-enhanced extraction
ISOTEC	In-Situ Oxidative Technologies, Inc.
kg/yr	kilograms per year
kW	kilowatt
LNAPL	light nonaqueous-phase liquid
µg/L	micrograms per liter
MCAF	Marine Corps Air Facility
MCL	maximum contaminant level
mg/L	milligrams per liter
mmHg	millimeters of mercury
MMR	Massachusetts Military Reservation
MSL	mean sea level
NPDES	National Pollutant Discharge Elimination System
NAVWPNSTA	Naval Weapons Station Seal Beach
O3	ozone
O&M	operation and maintenance
OCWD	Orange County Water District
OU	operable unit
PAC	powdered activated carbon
PAH	polynuclear aromatic hydrocarbon
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PF	pneumatic fracturing
POTW	Publicly Owned Treatment Works
ppm	parts per million
PRB	permeable reactive barrier

QA	quality assurance
QC	quality control
RBC	rotating biological contactors
RCRA	Resource Conservation and Recovery Act
RDX	cyclotrimethylenetrinitramine
redox	reduction-oxidation
ROD	record of decision
RTDF	Remediation Technologies Development Forum
scfm	standard cubic feet per minute
SERP	Steam-Enhanced Recovery Process
SITE	Superfund Innovative Technology Evaluation
SIVE	Steam Injection and Vacuum Extraction
STAR	Science, Technology, and Research
SPH	six-phase heating
SVE	soil vapor extraction
SVOC	semivolitile organic compound
TAN	Test Area North
TCA	trichloroethane
TCE	trichloroethene
TCP	trichloropropane
TNT	trinitrotoluene
TPH	total petroleum hydrocarbons
TSD	treatment, storage, and disposal
U.S.EPA	United States Environmental Protection Agency
UV	ultraviolet
VC	vinyl chloride
VEE	vacuum-enhanced extraction
VOC	volatile organic compound
Zimpro	Zimpro Environmental, Inc.

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Revised Appendix R-D
COST DEVELOPMENT SUMMARIES

R-D1 METHODOLOGY

Cost estimates for this RFS were prepared following United States Environmental Protection Agency technical guidance (U.S. EPA 1987, 1988) and the National Oil and Hazardous Substances Pollution Contingency Plan. The primary source of cost data was subcontractor quotes. Microsoft Excel spreadsheets were used to tabulate annual cost basis and calculate the net present values in 01 January 2005 dollars.

R-D1.1 DESCRIPTION OF RACER 99

R-D1.2 COST ESTIMATE COMPONENTS

Cost estimates for the IR Site 70 remedial alternatives include direct capital costs, direct operation and maintenance (O&M) costs, indirect costs, contingency allowances, and escalation costs.

- Direct capital costs cover those items needed to develop, construct and implement a remedial action. Direct capital costs include expenditures incurred for engineering, reports, construction, equipment, subcontractors, and direct support labor.
- Direct O&M costs refer to those post construction items necessary to ensure the continued effectiveness of a remedial action. Typical O&M expenses include operating labor, consumable materials (oil emulsion), administration, services (such as laboratory services), sampling and monitoring wells, 5-year reviews, and other essentials associated with operation and maintenance of the installed capital components.
- Indirect costs include all other expenses necessary to support the construction that cannot be directly associated with a specific equipment item or remedial activity. Indirect costs are comprised of general conditions consisting of overall project management, overhead, bonds and insurance, home office support, taxes, and profit. For Alternative 11, these indirect expenditures are implicitly included in the detailed cost analysis, as a portion of the direct capital and O&M costs.
- Contingency allowances are assumed to be 20 percent of the total cost of each alternative. The size of the contingency allowance would be expected to decrease as cost estimates are prepared during subsequent phases of design, after a remedial alternative has been selected and is proceeding toward implementation
- Escalation costs account for the increase in project expenditures over time simply due to inflation. For this RFS, as with the FS (BNI, 2002), an annual inflation rate of 2.5 percent was assumed.

R-D1.3 NET PRESENT VALUE

The net present value (NPV) of Alternative 11 was calculated using a 4.5 percent discount rate. The NPV for total O&M costs was developed by summing the annual O&M costs multiplied by the present value factor:

$$(P / f, i, n) = \sum \frac{1}{(1+i)^n}$$

Where: P/f equals the present value of a future amount
I equals the interest rate (ie., 7 percent)
n equals the year in which O&M costs are incurred

The NPV of the annual O&M costs was then added to the capital cost estimate to develop the overall NPV cost for each alternative.

The interest rate used in the NPV calculations (7 percent) represents the assumed investment rate of return on government securities. It is the sum of the assumed inflation rate (2.5 percent) and the anticipated real (inflation-adjusted) cost of money to the United States Treasury over the 30-year period considered in this RFS.

R-D1.4 GENERAL ASSUMPTIONS

Assumptions that influence the cost of implementing the passive enhanced bioremediation remedial alternative at IR Site 70 were based on general engineering practices. The following general assumptions were used to develop cost estimates for Alternative 11 in this RFS.

- All capital costs are based on 2004 dollars (based on quotes received from subcontractors).
- Project start date is assumed to be 01 January 2005.
- NPV is calculated in terms of 01 January 2005 dollars.
- O&M cost would be incurred beginning in 01 July 2005 and continue thereafter as required by each alternative.
- The sites are accessible and would not require specialized equipment or services for installation of wells, treatment systems, and conveyance pipelines, other than what would normally be employed to accomplish the work.
- The groundwater treatment systems would be installed within the property boundaries of NAVWPNSTA Seal Beach.
- All operations would be conducted using U.S. EPA Level D protective clothing or less where applicable, and only after safety and health monitoring is completed where necessary
- No disposal of hazardous materials is included unless specified.

D2 COST ESTIMATES FOR IR SITE 40

R-D3 COST ESTIMATES FOR IR SITE 70

R-D3.1 ALTERNATIVE 6 – HYDRAULIC CONTAINMENT (DISSOLVED PLUME) AND *IN SITU* TREATMENT (DNAPL AREA)

R-D3.2 ALTERNATIVE 7 – HYDRAULIC CONTAINMENT (DISSOLVED PLUME) AND PUMP AND TREAT (DNAPL AREA)

R-D3.3 ALTERNATIVE 9 – PUMP AND TREAT (DISSOLVED PLUMES) AND *IN SITU* TREATMENT (DNAPL AREA)

R-D3.4 ALTERNATIVE 10 – PUMP AND TREAT (DISSOLVED PLUME) AND PUMP AND TREAT (DNAPL AREA)

R-D3.5 ALTERNATIVE 11 – BIOSTIMULATION AND BIOAUGMENTATION (DNAPL AREA AND DISSOLVED PLUME) USING ENHANCED BIOREMEDIATION

Alternative 11 would employ *in situ* enhanced biostimulation and bioaugmentation by using emulsified oil amended with dechlorinating bacteria (*Dehalococcoides ethenogenes*) to reduce the mass of VOCs in the suspected dense non-aqueous phase liquid (DNAPL) area as well as biobarriers transecting the downgradient dissolved plumes. A laboratory treatability study and pilot testing has been included in the cost estimate (Tables R-D-19 and R-D-20) due to the innovative nature of the technology. It is assumed for costing purposes that the required duration of treatment for the source area will be 15 years and five to ten years for the dissolved plume treatment, following which natural attenuation processes would complete the remediation.

In the DNAPL source area, full-scale implementation of this alternative would employ a grid of standard 2- to 4-inch diameter wells installed using hollow stem auger to a depth of 50 ft below ground surface (bgs) to deliver the oil emulsion and bacterial culture to the aquifer. Each well will be screened between 35 and 50 ft bgs using v-wrapped screens. For cost-estimating purposes, it is assumed that treatment would occur over an approximate 200 by 300 ft area. Assuming a 13 ft radius of influence during injection of the emulsified vegetable oil (EVO), approximately 48 wells will be required. In addition to the source area, impacted groundwater has migrated toward the northern site boundary. Biological treatment to contain the source area would be achieved by injecting electron donor along an approximate 200 ft length of the northern site boundary, which would require an additional 8 injection wells (for a total of 56 wells for the source area). Costs for well installation were estimated from quotes from subcontractors.

Table R-D-19
Cost Estimate Assumptions
Alternative 11 - Biostimulation and Bioaugmentation (DNAPL Area and Dissolved Plume) Using Passive Biobarriers

Components	Assumptions
Source Area Treatment	Number of injection wells installed/installation depth: 56 wells installed to 50 ft bgs, screened from 35 to 50 ft bgs, 48 installed on a grid pattern at 25 ft centers in the high concentration (>1,000 □g/L)source area, 8 wells installed in a linear biobarrier to the north of the source area to provide hydraulic containment Well construction technique: Hollow-stem auger drilling, 4 inch schedule 40 PVC with V-wrapped screens Bioaugmentation: required to stimulate complete dechlorination, application rate of 10 L per injection well, KB-1™ culture used (total of 560 L) Amendment rate and type: emulsified vegetable oil supplied by RNAS, shipped to site in 1,000 L totes pre-emulsified, applied at a rate of 1% soil saturation (oil, 2.1% emulsion), assume one injection every two years for 15 years necessary
Plume Treatment – First Sand Unit	Number of injection wells installed/installation depth: 4 biobarriers installed 500 ft apart (two 500 ft long, two 800 ft long) and oriented perpendicular to the groundwater flow direction. Biobarriers would consist of either 32 wells (800 ft long barrier) or 20 wells (500 ft long barrier) installed at 25 ft centers to 100 ft deep, screened from 70 to 100 ft bgs. Biobarrier spacing assumes an approximate five year flushing rate between barriers Well construction technique: Hollow-stem auger drilling, 4 inch schedule 40 PVC with V-wrapped screens Bioaugmentation: required to stimulate complete dechlorination, application rate of 10 L per injection well, KB-1™ culture used (total of 1,040 L) Amendment rate and type: emulsified vegetable oil supplied by RNAS, shipped to site in 1,000 L totes pre-emulsified, applied at a rate of 0.5% soil saturation (oil, 1% oil emulsion), assume one injection every two years for 4 to 6 years
Plume Treatment – Second Sand Unit	Number of injection wells installed/installation depth: 2 biobarriers installed 500 ft apart (one 500 ft long, one 800 ft long) and oriented perpendicular to the groundwater flow direction. Biobarriers would consist of either 32 wells (800 ft long barrier) or 20 wells (500 ft long barrier) installed at 25 ft centers to 160 ft deep, screened from 120 to 160 ft bgs. Biobarrier spacing assumes a five year flushing rate between barriers Well construction technique: mud rotary drilling, 4 inch schedule 40 PVC with V-wrapped screens Bioaugmentation: required to stimulate complete dechlorination, application rate of 10 L per injection well, KB-1™ culture used (total of 560 L) Amendment rate and type: emulsified vegetable oil supplied by RNAS, shipped to site in 1,000 L totes pre-emulsified, applied at a rate of 0.5% soil saturation (oil, 1% oil emulsion), assume one injection every two years for four years
Monitoring	Number of new wells/installation depth/screen length: 4 wells / 50 ft bgs / 15 ft (source monitoring wells) 28 wells / 90 ft bgs / 15 ft (sand unit 1, plume monitoring wells, 3 upgradient and 3 downgradient of each of four barriers, plus 1 between the four barriers) 14 wells / 150 ft bgs / 15 ft (sand unit 2, plume monitoring wells, 3 upgradient and 3 downgradient of each of two barriers, plus 2 between the two barriers) Well construction materials: Schedule 40 PVC, 4 inch I.D Well construction technique: Hollow-stem auger drilling for wells installed above 100 ft bgs, mud rotary for wells installed below 100 ft bgs Number of wells sampled per year: Year 1: 71 wells (63 wells plume, 8 source, quarterly sampling) Year 2: 71 wells (63 wells plume, 8 source, semi-annual sampling) Years 3 to 6: 71 wells (63 wells plume, 8 source, annual sampling) Years 7 to 15: 13 wells (4 wells plume (for MNA monitoring), 9 source, annual sampling) Sample frequency: Quarterly (first year), biannually (second year), annually (years 3 to 15 in the plume to monitor for MNA, and years 3 to 15 in the source area) Analyses: VOCs — U.S. EPA Method 8260B [low level] Dissolved metals (iron II, manganese, arsenic) — U.S. EPA Method 6010B Total organic carbon — U.S. EPA Method 415 Dissolved gases (methane, ethane, ethene) — U.S. EPA RSK-175 Anions (SO_4, Cl, NO_3, S, PO_4) — U.S. EPA Method 300.0 Volatile fatty acids (lactate, acetate, butyrate, propionate, formate, hexanoate) — U.S. EPA 8015 Modified GC/FID Field parameters (temperature, pH, ORP, specific conductivity, water elevation, DO) — field meter QA/QC samples — 20% Monitoring Duration: 6 years for active bio, 9 years following for MNA (plume), 15 years (source)
Periodic Review	After 5 years

Acronyms/Abbreviations:
- bgs – below ground surface
- IR – Installation Restoration (Program)
- MNA – monitored natural attenuation
- ORP – oxidation reduction potential
- PVC – polyvinyl chloride
- QA/QC – quality assurance / quality control
- RNAS – Remediation and Natural Attenuation Services
- SO_4, Cl, NO_3 & S – sulfate, chloride, nitrate and sulfide
- U.S. EPA – United States Environmental Protection Agency
- VOC – volatile organic compound

Table R-D-20
Cost Estimate Summary
Alternative 11 - Biostimulation and Bioaugmentation (DNAPL Area and Dissolved Plume) Using Passive Biobarriers

Description	Cost
Capital Costs	
Groundwater monitoring wells (installation of 42 wells)	$166,000
Oil amendment injection wells (installation of 212 wells)	$1,097,000
Temporary oil injection equipment	$100,000
Professional labor (includes Proposed Plan, Record of Decision, Remedial Action Plan, workplan, design and startup, well installation oversight)	$2,162,000
Site characterization and laboratory treatability study	$800,000
Total capital costs (based on January 2005 dollars, including profit and overhead)	**$4,325,000**
O&M Costs	
Oil emulsion (15 year supply)	$4,199,000
Oil injection labor (15 years)	$574,000
Monitoring (includes 20% QA/QC, sampling, analysis, mobilization and labor)	$2,003,000
Gene-Trac analysis	$108,000
KB-1™	$602,000
Annual Professional Costs (five year reviews, annual reporting, field program start-up and management)	3,865,000
Total O&M Costs (including 2.5% inflation per annum)	**$11,351,000**
Subtotal	**$15,676,000**
TOTAL (including 20% contingency)	**$18,810,000**
NET PRESENT VALUE (based on January 2005 dollars)	**$14,663,000**

EVO would be delivered to the source area to achieve a residual oil saturation of 1% of the pore volume. Groundwater from the intermediate zone will be pumped to provide the site water for mixing. Bulk pricing of the EVO is currently priced at $2.64/kg delivered to the site, for a cost of $4,500 per well. EVO would be injected once every two years into the source area. It is likely that the lifespan of the oil will exceed these estimates, which would reduce costs significantly; however, there is not yet enough field implementation data available to accurately gauge the oil lifespan in the subsurface. For costing purposes, we have assumed a 15-year duration is required to treat the DNAPL source, after which MNA is assumed to provide adequate mass control.

In the dissolved phase plume, full-scale implementation of this alternative would employ a series of biobarriers oriented perpendicular to the direction of plume migration along the groundwater flowpath. The number of biobarriers used impacts the length of time for plume remediation; a greater number of biobarriers would decrease the remediation time frame but increase the installation cost. For costing purposes, the biobarrier transects would be placed at a spacing equal to 5 years of groundwater flow. Based on currently available hydrogeologic data, this may be achieved by spacing the biobarriers 500 feet apart within the first and second sand units at the site. Based on the distribution of VOCs above a concentration of 50 ug/L (the effective bioremediation action level), the biobarriers would be approximately 500 to 800-feet wide. A total of 6 biobarriers would be required (four in the upper sand unit, 2 in the lower sand unit).

For costing purposes, three biobarriers are assumed to have an average width of 500 feet and be comprised of 20 wells each, for a total of 60 wells for these biobarriers (20 wells in the second sand unit, 40 in the first sand unit). The remaining three biobarriers are assumed to have an average width of 800 feet, which will require 32 wells per barrier, or 96 wells total (32 wells in the second sand unit, 64 in the first sand unit). Injection wells within each biobarrier will be spaced on 25 foot centers, which will provide some overlap of the oil distribution based upon the 25 foot radius of influence observed in previous pilot tests (BNI, 2004a). Shallower wells will be standard 2 to 4-inch diameter wells installed by using hollow-stem auger to a depth of 100 ft bgs. Each well in the first sand unit will be screened between 70 and 100 ft bgs by using v-wrapped screens. Wells screened in the second sand unit will also be standard 2- to 4-inch diameter wells installed by using mud rotary (due to heaving sands) to a depth of 160 ft bgs. Each deeper well will be screened between 120 to 160 ft bgs by using v-wrapped screens.

The 6 biobarriers will require a total of 156 injection wells to dissect the VOC plume. Assuming a 13-foot radius of injection and screened intervals of 30 and 40 ft in the shallower and deeper sand units respectively, each deeper well would require 1,850 kg of EVO every two years (assuming biannual injections) and each shallower well would require 1,250 kg of EVO every two years. Therefore, the 156 injection points would require a total of 225,000 kg of EVO every two years. This would cost approximately $594,000 every two years, not accounting for inflation. For costing purposes, it was assumed that the passive biobarriers in the plume would be required for between 4 to 6 years (6 years nearer the source area, 4 years at the toe of the plume), after which MNA would provide adequate mass control.

The oil injections would occur using temporary injection equipment consisting of a proportional feed system designed to introduce an amendment solution into a water stream at a known ratio of the delivered flow rate. The proportional feed system will consist of multi-channels (upwards of 30 to 40 channels) allowing for injections into multiple wells to occur at the same time. Groundwater would be extracted from one or more nearby wells, blended and fed through the proportional feed system and amended with the oil emulsion prior to splitting of the flow into up to 40 injection wells. The injection equipment will be temporary and will be manually operated. Equipment required to construct each multi-channel injection system includes up to 40 proportional feed injectors, flow control elements (valves, flow meters, etc.), groundwater extraction pumps (up to 10), piping, and in-line filters. The oil emulsion will be injected directly from the shipping containers, so no permanent storage is required. Injections of the required amounts of fluids will require 8 to 11 days (assuming injection rates of 5 and 10 gpm are achievable into each source and plume area wells respectively) per biobarrier (up to 40 wells at a time), requiring a total of 73 10-hour days. The time for injection may be altered depending on achievable injection rates.

Bioaugmentation would be used to stimulate complete biodegradation of the chlorinated ethenes to innocuous end products (ethene, carbon dioxide). A commercially available mixed culture containing the dechlorinating microorganism *Dehalococcoides ethenogenes*, called KB-1™, would be added to each injection well at the rate of 10 L per well one month after injection of the oil emulsion.

R-D4 REFERENCES

United States Environmental Protection Agency. 1987. Remedial Action Costing Procedures Manual. EPA/600/8-87/049. October.

_______. 1988. Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA. OSWER Directive 9355.1. EPA/540/G-89/004. Interim Final. October.

U.S. EPA. *See* United States Environmental Protection Agency.

REVISED APPENDIX R-E2

IR SITE 70 TRANSPORT MODEL

FOREWORD

This revised appendix provides a description of the numerical flow and transport model that was developed to analyze remedial Alternative 11 involving bioremediation of both the source and plume for Installation Restoration (IR) Program Site 70 at Naval Weapons Station Seal Beach (NAVWPNSTA Seal Beach), Seal Beach, California. The Table of Contents (TOC) in this Appendix provides a cross reference between Appendix E-2 in the original Feasibility Study (FS; BNI, 2002) and the revised Appendix R-E2 of the RFS. The shaded portions of the TOC reflect elements of Appendix E of the FS that have not been altered for the RFS and are thus incorporated by reference. Unshaded portions of the TOC reflect text that has been added or revised within the RFS.

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TABLE OF CONTENTS

FIGURES

Figure

Table of Contents

Figure

TABLES

Table of Contents

Table

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ACRONYMS/ABBREVIATIONS

bgs	below ground surface
BNI	Bechtel National, Inc.
cm/s	centimeters per second
cm3/g	cubic centimeters per gram
cm2/min	square centimeters per minute
3-D	three-dimensional
DCA	dichloroethane
DCE	dichloroethene
De	aqueous diffusion coefficient
DNAPL	dense nonaqueous-phase liquid
ERSE	Extended Removal Site Evaluation
foc	fraction of organic carbon
FS	feasibility study
ft-1	per foot
ft/day	feet per day
ft2/min	square feet per minute
g/cm3	grams per cubic centimeter
g/mole	grams per mole
gpm	gallons per minute
IR	Installation Restoration (Program)
kd	distribution coefficient
koc	organic carbon-to-water partitioning coefficient
kg/L	kilograms per liter
lb	pound
lb/ft3	pounds per cubic foot
µg/L	micrograms per liter
mg/L	milligrams per liter
MSL	mean sea level
NAVWPNSTA	Naval Weapons Station Seal Beach

PCE	tetrachloroethene
TCA	trichloroethane
TCE	trichloroethene
U.S. EPA	United States Environmental Protection Agency
VOC	volatile organic compound
vol. %	volumetric percent
wt. %	weight percent

Revised Appendix R-E2

IR SITE 70 TRANSPORT MODEL

R-E2 INTRODUCTION

This revised appendix provides a description of the numerical flow and transport model that was developed to analyze remedial alternatives for Installation Restoration (IR) Program Site 70 for Alternative 11 involving bioremediation of both the source and plume. In most respects, the model developed by Bechtel (BNI, 2002) was recreated, to provide an equal basis of comparison between Alternative 11 and the alternatives discussed in the FS. Sections R-E2.2 and R-E2.3 provide overviews of the original conceptual and numerical models and highlight any changes made for Alternative 11. Sections R-E2.4 and R-E2.5 discuss the results of the Alternative 11 simulation and impact of model uncertainty.

R-E2.1 CONCEPTUAL MODEL

Results of the ERSE showed that volatile organic compounds (VOCs), primarily trichloroethene (TCE), have migrated downward through the shallow stratigraphic units into deeper zones. The highest VOC concentrations in groundwater are located in the interbedded unit but are also present at lower concentrations in the underlying first and second sand units. The deeper portion of the plume, in the first and second sand units, has migrated beyond IR Site 70. The conceptual model and the subsequent numerical model focus on the area of the plume within and beyond IR Site 70, where the influence of the remedial Alternative 11 will be evaluated, and include all stratigraphic units where VOCs have been consistently detected.

E2.1.1 Hydrogeology

The site-specific hydrostratigraphic units are shown in Figure E2-1. The units include surficial soils, shallow clay unit, interbedded unit, first sand unit, shell horizon, second sand unit, and deep clay unit. The shallow clay unit and the deep clay unit are continuous layers composed of fine-grained material (clay and silt). Coarser-grained soils (sand and silty sand) comprise portions of the interbedded unit and dominate the first sand unit, shell horizon, and second sand unit. The water table is located in the shallow clay unit (BNI, 2002).

Step tests were performed in wells screened within the upper portion of the interbedded unit, and within the upper portion of the first sand unit. A 5-day pumping test and a 3-month pilot test were performed using well EW-70-01, screened in the interbedded unit.

Natural hydrogeologic boundaries within or adjacent to the site appear to be absent. Regional hydrogeologic boundaries beyond the study area (e.g., groundwater divide, river, or ocean) are distant from IR Site 70 and are, therefore, unlikely to affect the remedial alternative model for IR Site 70.

Recharge from precipitation infiltrating within IR Site 70 is expected to be negligible because the majority of the area is covered with pavement and buildings. Recharge beyond IR Site 70 is possible in areas of bare soil and unlined stormwater channels, but recharge is likely most significant in areas of agricultural irrigation and domestic lawn watering.

Groundwater discharge occurs at water supply wells that were identified in the ERSE Report. These supply wells are located beyond IR Site 70, but within the Navy property, and are screened below the deep clay unit identified at IR Site 70. Although it is not certainly known that these supply wells extract groundwater from above the deep clay unit, it appears likely that they affect the hydraulic gradients within the plume area.

Water level data collected during the ERSE investigation, EW-70-01 pumping test, and EW-70-01 pilot test indicated seasonal water level fluctuations with a range of 5 feet or more at monitoring wells in the interbedded unit, first sand unit, and second sand unit. Potentiometric head differences between the interbedded unit and the first sand unit range from 0.5 to 4 feet downward and are typically 1 to 3 feet. Head differences between the first and second sand units are much less and range from 0.0 to 0.3 foot downward. The head differences and seasonal fluctuations are suspected to result from local groundwater usage by agricultural wells to the southeast, possibly from groundwater usage by more distant municipal wells to the north, and from groundwater injection to the west.

The horizontal hydraulic gradient is generally southeast. However, the shallow groundwater appears to have a seasonal reversal from southeast to northwest. Hydraulic gradients determined from water levels measured during the ERSE investigation (ERSE Report, Appendix G3) were:

- interbedded unit – 0.0007 to 0.001 southeast in August 1996, and 0.0005 to 0.002 in March and April 1998;
- upper portion of first sand unit – 0.001 – 0.003 southeast in August 1997, and 0.0005 to 0.002 southeast in March and April 1998; and
- lower portions of first sand unit and second sand unit – 0.0005 to 0.003 southeast, with average of 0.001, in April 1998.

Hydraulic gradients determined from water levels measured during the EW-70-01 pilot test (Technical Memorandum No. 5, Figures 3-9 through 3-14 [BNI, 1999c]) are:

- interbedded unit – affected by pumping test and pilot test, but with apparent gradient of 0.0006 northwest in November 1998;
- upper portion of first sand unit – 0.0009 southeast in November 1998, and 0.0006 south-southeast in February 1999; and
- Lower portions of first sand unit and second sand unit – 0.002 southeast in November 1998, and 0.006 southeast in February 1999.

The horizontal hydraulic gradient is slightly reduced in the winter in the first and second sand units, while the interbedded unit shows a gradient reversal. A median horizontal hydraulic gradient for the first and second sand units is 0.001 to 0.0015 southeast.

R-E2.1.2 Plume Interpretation

A two-dimensional interpretation was developed by BNI (2002) for several depth intervals of the IR Site 70 TCE plume using SURFER® software (Golden Software 1997) and a kriging technique with logarithmic concentration values. An interpolation grid spacing of 10 feet was used for samples from depth intervals of less than 40 feet bgs, 40 to 62 feet bgs, 76 to 100 feet bgs, and 133 to 172 feet bgs. Measured concentrations were interpolated to the grid points in order to prepare an initial concentration input file for the FS transport model. The grid is 4,000 feet in length (east-west) and 4,000 feet in width (north-south). The TCE concentration data, sorted by decreasing total chlorinated alkanes and alkenes, is listed in Table E2-1.

The resulting SURFER-generated contours are shown in Figures E2-2A through E2-2D for the four depth intervals. Figure E2-2E shows sample locations for depths from 183 to 191 feet bgs, but only one sample slightly exceeded 5 μg/L. Maximum concentrations were used to represent data from multiple samples within a specified depth interval at an individual boring. The resulting contours are similar to the manual interpretation presented in the ERSE Report, Figures 4-34 through 4-39B, although the depth intervals are slightly different. These contours are essentially the same as presented in Technical Memorandum No. 5, Figures J-1 through J-4 (BNI, 1999c), but have been extended here across the entire plume. With detection limits of 2 to 4 μg/L typically, SURFER contours for concentrations below 5 μg/L are not likely to be accurate and are not presented. For the transport model simulations, initial plume concentrations below 5 μg/L were neglected. The SURFER-generated contours from the FS were used to provide the basis of the initial plume contours for the simulations of Alternative 11.

The 10,000-μg/L contour in Figures E2-2A through E2-2C is assumed to represent a source area potentially containing residual dense nonaqueous-phase liquid (DNAPL) TCE. One percent of the solubility of TCE is 11,000μg/L. Residual TCE may be present within the interbedded unit (as discussed in the ERSE Report). Residual TCE consists of DNAPL trapped in individual pore spaces and separated by water-filled pores and possibly includes ganglia.

R-E2.2 NUMERICAL MODEL DEVELOPMENT

This section describes the modeling codes, grid, layers, hydraulic properties, and transport properties incorporated into the RFS numerical model for Alternative 11. The flow model properties are summarized in Table R-E2-2, and the transport model properties are summarized in Table R-E2-3.

Table E2-2
IR Site 70 - Flow Model Layer Properties

Model Layer No.	Elevation (ft, MSL) Top to Bottom	Layer Thickness, m (feet)	Stratigraphic Unit[a]	MODFLOW LAYCON CODE[b]	Hydraulic Conductivity, K[c] Horizontal, K_h (cm/s)	Vertical, K_v (cm/s)	Horizontal, K_h (ft/day)	Vertical, K_v (ft/day)	Vertical Anistropy K_v/K_h (cm/s)	Layer Transmissivity,[d] T (ft²/min)	Total Porosity,[e] n	Effective Porosity,[f] n_e	Specific Yield,[g] S_y	Specific Storage,[h] S_s (ft^{-1})	Storage Coefficient,[i] S
--	9 to 6.5	2.5	Surficial soils		(Unsaturated surficial soils are included with model layer 1 for shallow clay)										
1	6.5 to -10.5	17	Shallow clay	1	1.0 E-6	1.0 E-7	0.00283	0.000283	1/10	--	0.44	0.37	0.04	--	--
2	-10.5 to -25.5	15	Interbedded unit - upper	3	0.0036	3.6 E-4	10	1.0	1/10	0.1	0.40	0.33	0.21	0.00027	0.004
3	-25.5 to -30.5	5	Interbedded unit - lower	3	5.0 E-6	1.0 E-7	0.0142	0.000283	1/50	4.9 E-5	0.44	0.37	0.06	1.0 E-5	5.0 E-5
4	-30.5 to -52.5	22	First sand unit - upper	0	0.0056	5.6 E-4	16	1.6	1/10	0.24	0.37	0.31	0.21	1.0 E-5	2.2 E-4
5	-52.5 to -72.5	20	First sand unit - middle	0	0.014	0.0014	39	3.9	1/10	0.54	0.33	0.27	0.21	1.0 E-5	2.0 E-4
6	-72.5 to -91	18.5	First sand unit - lower	0	0.014	0.0014	39	3.9	1/10	0.5	0.33	0.27	0.21	1.0 E-5	1.9 E-4
7	-91 to -104	13	Shell horizon	0	0.024	0.005	69	13.8	1/5	0.62	0.36	0.30	0.26	1.0 E-5	1.3 E-4
8	-104 to -133.5	29.5	Second sand unit - upper	0	0.024	0.002	69	6.9	1/10	1.4	0.36	0.30	0.26	1.0 E-5	3.0 E-4
9	-133.5 to -163	29.5	Second sand unit - lower	0	0.024	0.005	69	13.8	1/5	1.4	0.36	0.30	0.26	1.0 E-5	3.0 E-4
10	-163 to -175	12	Deep clay unit	0	1.0 E-6	1.0 E-7	0.00283	0.000283	1/10	2.4 E-5	0.44	0.37	0.04	1.0 E-5	1.2 E-4

Notes:
[a] Modified from Technical Memorandum No. 5, Table 4.1 (BNI, 1999b); includes further division of first and second sand units, addition of deep clay unit, lower hydraulic conductivity for fine-grained units, reduced anisotropy ratio of K_v/K_h
[b] MODFLOW LAYCON code: 1 indicates unconfined layer; 3 indicates confined/unconfined layer (can switch depending on water level); and 0 indicates confined layer.
[c] Horizontal hydraulic conductivities are based upon the following:
First sand unit (upper portion): based on model calibration to step drawdown test data (Technical Memorandum No. 5, BNI 1999b);
First sand unit (lower portion) and second sand unit: based on slug test results (Table E2.4);
Shallow clay, lower portion of interbedded unit, and deep clay unit: assumed values, typical for clay; slightly higher value for lower portion of interbedded unit, which indicates silts.
Vertical hydraulic conductivites are based upon the assumed values for vertical anisotropy:
Generally assumed K_v/K_h = 1/10, which is typical for stratified materials;
Shell horizon and lower portion of second sand unit: K_v/K_h = 1/5, based on general absence of clays and silts;
Lower portion of interbedded unit: K_v/K_h = 1/50, which provides K_v similar to clay units (low K_v is required to achieve calibration to measured head differences).
[d] Transmissivity for model layer 2 is based on the shallow pilot test data (Technical Memorandum No. 5, BNI, 1999b); other transmissivities are calculated from the horizontal hydraulic conductivity multiplied by the saturated layer thickness ($T = K_h m$).
[e] Total porosity is based on laboratory tests; results are listed in Table E2.5.
[f] Effective porosity is assumed to be 83 percent of total porosity (ne = 0.83n), based on grain size evaluation (Technical Memorandum No. 5, Table I.2, BNI, 1999b).
[g] Specific yield is based on typical values from literature of 0.02 to 0.07 for clay and sandy clay, 0.08 for silt, 0.21 for fine sand, and 0.26 for medium sand (Johnson, 1967).
[h] Specific storage is based on an assumed value of 0.00001 ft 1 typical for confined layers, but model layer 2 is based upon the storage coefficient determined from the pilot test results (Technical Memorandum No. 5, BNI 1999b)
[i] Storage coefficient is based on specific storage multiplied by layer thickness ($S = S_s m$).

Acronyms/Abbreviations:
cm/s – centimeters per second
ft^{-1} – per foot
ft/day – feet per day
ft²/min – square feet per minute
ft, MSL – feet (in relation to) mean sea level

Table E2-3
IR Site 70 - Solute Transport Model Properties

Model Layer No.	Model Layer Depth (ft bgs)	Stratigraphic Unit[a,b]	Initial Concentration Data	Soil Bulk Density[c] ρ_b (g/cm^3)	Soil Bulk Density[c] ρ_b (kg/ft^3)	Porosity[d] Total Porosity, n	Porosity[d] Effective Porosity, n_e	Soil Organic Carbon Content,[e] f_{oc} (percent)	Dispersivity[f] Longitudinal, α_L (feet)	Dispersivity[f] Transverse/Longitudinal, α_T/α_L	Dispersivity[f] Vertical/Longitudinal, α_v/α_L	Diffusion Coefficient D_e (cm^2/s)	Diffusion Coefficient D_e (ft^2/day)	Distribution Coefficient[h] K_d (mL/g)	Distribution Coefficient[h] K_d (ft^3/kg)	Retardation Factor,[i] R	Degradation Rate[j] Dissolved Solute (1/day)	Degradation Rate[j] Sorbed Phase (1/day)
1	0 to 19.5	Shallow clay	13-40 ft bgs (Fig. E2-2A)	1.51	42.8	0.44	0.37	0.46	2.875	0.1	0.025	8.30 E-6	7.72 E-4	0.58	0.02	3.4	4.2 E-4	4.2 E-4
2	19.5 to 34.5	Interbedded unit - upper	13-40 ft bgs (Fig. E2-2A)	1.58	44.7	0.4	0.33	0.11	2.875	0.1	0.025	8.30 E-6	7.72 E-4	0.14	0.0049	1.7	4.2 E-4	4.2 E-4
3	34.5 to 39.5	Interbedded unit - lower	13-40 ft bgs (Fig. E2-2A)	1.51	42.8	0.44	0.37	0.46	2.875	0.1	0.025	8.30 E-6	7.72 E-4	0.58	0.02	3.4	4.2 E-4	4.2 E-4
4	39.5 to 61.5	First sand unit - upper	40-62 ft bgs (Fig. E2-2B)	1.68	47.6	0.37	0.31	0.14	2.875	0.1	0.025	8.30 E-6	7.72 E-4	0.18	0.0062	2	4.2 E-4	4.2 E-4
5	61.5 to 81.5	First sand unit - middle	40-62 ft bgs (Fig. E2-2B)	1.79	50.7	0.33	0.27	0.05	2.875	0.1	0.025	8.30 E-6	7.72 E-4	0.063	0.0022	1.4	0	0
6	81.5 to 100	First sand unit - lower	76-110 ft bgs (Fig. E2-2C)	1.79	50.7	0.33	0.27	0.05	2.875	0.1	0.025	8.30 E-6	7.72 E-4	0.063	0.0022	1.4	0	0
7	100 to 113	Shell horizon	76-110 ft bgs (Fig. E2-2C)	1.79	50.7	0.36	0.3	0.05	2.875	0.1	0.025	8.30 E-6	7.72 E-4	0.063	0.0022	1.4	0	0
8	113 to 142.5	Second sand unit - upper	133-172 ft bgs (Fig. E2-2D)	1.79	50.7	0.36	0.3	0.05	2.875	0.1	0.025	8.30 E-6	7.72 E-4	0.063	0.0022	1.4	0	0
9	142.5 to 172	Second sand unit - lower	133-172 ft bgs (Fig. E2-2D)	1.79	50.7	0.36	0.3	0.05	2.875	0.1	0.025	8.30 E-6	7.72 E-4	0.063	0.0022	1.4	0	0
10	172 to 184	Deep clay unit	0	1.51	42.8	0.44	0.37	0.46	2.875	0.1	0.025	8.30 E-6	7.72 E-4	0.58	0.02	3.4	0	0

Model Layer No.	Model Layer Depth (ft bgs)	Stratigraphic Unit[a,b]	Initial Concentration Data	Distribution Coefficient[k] PCE K_d (mL/g)	TCE K_d (mL/g)	cisDCE K_d (mL/g)	VC K_d (mL/g)	Ethene K_d (mL/g)	Chloride K_d (mL/g)
1	0 to 19.5	Shallow clay	13-40 ft bgs (Fig. E2-2A)	1.83	0.58	0.58	1.45	1.39	0
2	19.5 to 34.5	Interbedded unit - upper	13-40 ft bgs (Fig. E2-2A)	0.44	0.14	0.14	0.35	0.33	0
	34.5 to 39.5	Interbedded unit - lower	13-40 ft bgs (Fig. E2-2A)	1.83	0.58	0.58	1.45	1.39	0
4	39.5 to 61.5	First sand unit - upper	40-62 ft bgs (Fig. E2-2B)	0.56	0.18	0.18	0.44	0.42	0
5	61.5 to 81.5	First sand unit - middle	40-62 ft bgs (Fig. E2-2B)	0.20	0.063	0.063	0.16	0.15	0
6	81.5 to 100	First sand unit - lower	76-110 ft bgs (Fig. E2-2C)	0.20	0.063	0.063	0.16	0.15	0
7	100 to 113	Shell horizon	76-110 ft bgs (Fig. E2-2C)	0.20	0.063	0.063	0.16	0.15	0
8	113 to 142.5	Second sand unit - upper	133-172 ft bgs (Fig. E2-2D)	0.20	0.063	0.063	0.16	0.15	0
9	142.5 to 172	Second sand unit - lower	133-172 ft bgs (Fig. E2-2D)	0.20	0.063	0.063	0.16	0.15	0
10	172 to 184	Deep clay unit	0	1.83	0.58	0.58	1.45	1.39	0

Model Layer No.	Degradation Rate[l] Dissolved and Sorbed Solute (1/day) PCE Bioactive Zone	PCE Inter-Barrier Zone	TCE Bioactive Zone	TCE Inter-Barrier Zone	cisDCE Bioactive Zone	cisDCE Inter-Barrier Zone	VC Bioactive Zone	VC Inter-Barrier Zone	Ethene Bioactive Zone	Ethene Inter-Barrier Zone
1	0.173	0.010	0.173	0.003	0.173	0.002	0.173	0.003	0.173	0.0011
2	0.173	0.010	0.173	0.003	0.173	0.002	0.173	0.003	0.173	0.0011
	0.173	0.010	0.173	0.003	0.173	0.002	0.173	0.003	0.173	0.0011
4	0.173	0.010	0.173	0.003	0.173	0.002	0.173	0.003	0.173	0.0011
5	0.173	0.010	0.173	0.003	0.173	0.002	0.173	0.003	0.173	0.0011
6	0.173	0.010	0.173	0.003	0.173	0.002	0.173	0.003	0.173	0.0011
7	0.173	0.010	0.173	0.003	0.173	0.002	0.173	0.003	0.173	0.0011
8	0.173	0.010	0.173	0.003	0.173	0.002	0.173	0.003	0.173	0.0011
9	0.173	0.010	0.173	0.003	0.173	0.002	0.173	0.003	0.173	0.0011
10	0.173	0.010	0.173	0.003	0.173	0.002	0.173	0.003	0.173	0.0011

Notes:
- [a] Modified from technical Memorandum No. 5, Table 5-1 (BNI 1999b); included further division of first and second sand units, and addition of degradation rate for shallow layers.
- [b] Properties for fine-grained lower portion of interbedded unit and deep clay unit assumed to be the same as the shallow clay unit. Properties for the shell horizon assumed to be same as second sand unit
- [c] Soil bulk density from laboratory data (Table E2-5). Average soil bulk density of 1.79 used for layers 5 through 9
- [d] Total and effective porosity from Table E2-2.
- [e] Soil Organic Carbon content from laboratory data (Table E2-7); however, soil organic carbon content for layers 5 through 9 based on calibrated transport model for deep plume in ERSE Report (BNI 1998)
- [f] Dispersity values are based on the calibrated transport model for the deep plume in the ERSE report (BNI 1998), with α_L=2.5% of travel distance, where travel distance is assumed to be one-half the radius of influence measured from the shallow pilot test.
- [g] Diffusion coefficient based on literature value (E2-8).
- [h] Distribution coefficient used by BNI (200), $K_d = f_{oc} \times K_{oc}$ = 126 cm^3/g (U.S. EPA 1986)
- [i] Retardation factor, $R = 1 + (P_b/n_e) K_d$ (Freeze and Cherry 1979).
- [j] Degradation rate (used by BNI (2000) for pump and treat models) assumed negligible in deep portion of plume; shallow degradation rate based on literature value (Table E2-8)
- [k] Distribution coefficients used for Alternative 11 simulations correspond to mean K_{oc} values quoted in Aziz et al. (2000), where K_d was calculated from $K_d = f_{oc} \times K_{oc}$ (K_{oc} (PCE) = 398 L/kg, K_{oc} (TCE) = 126 L/kg), K_{oc} (cisDCE) = 126 L/kg, K_{oc} (VC) = 316 L/kg, K_{oc} (ethene) = 302 L/kg, and chloride assumed to be conservative (K_{oc} = 0)).
- [l] Reaction rate constants outside of the influence of the biostimulated zones are assumed to be the mean values quoted in the literature by Suarez and Rifai (1999). Due to the presence of degradation byproducts, natural attenuation was assumed to occur at all depths. Within the bioactive zones, a conservative estimate of 4 day half-lives is assigned to all variables except chloride, which is assumed to not degrade. Typical half-lives for chlorinated ethenes in biostimulated zones are hours to a few days (Major et al., 2002).

Acronyms/Abbreviations:
- cm^3/g - cubic centimeters per gram
- cm^2/s - square centimeters per second
- cm/sec - centimeters per second
- ft bgs - feet below ground surface
- ft^2/day - square feet per day
- ft^3/kg - cubic feet per kilogram
- PCE - tetrachloroethene
- TCE - trichloroethene
- cisDCE - cis-1,2-dichloroethene
- VC - vinyl chloride

R-E2.2.1 Modeling Codes

The groundwater flow and transport modeling codes used for simulating remedial Alternative 11 (bioremediation of source and plume) were Visual MODFLOW 2000 and RT3D2.5 respectively. The groundwater transport modeling code RT3D2.5 simulates advection, dispersion, and decay of contaminants in 3-D flow systems, and also simulates the sequential decay of TCE through to cis-1,2-dichloroethene (cisDCE), vinyl chloride (VC), ethene, and chloride through reductive dechlorination. RT3D is designed to be used in conjunction with a block-centered finite difference flow model such as MODFLOW.

R-E2.2.2 Model Grid, Boundaries, and Sinks

A horizontal grid of 25-foot spacing was used for Alternative 11 within IR Site 70. The grid spacing was then increased to 50 feet, 100 feet, 200 feet, and finally 400 feet, approaching the model boundaries. The model horizontal dimensions are 18,000 by 11,000 feet. The model horizontal grid is shown in Figure R-E2-4.

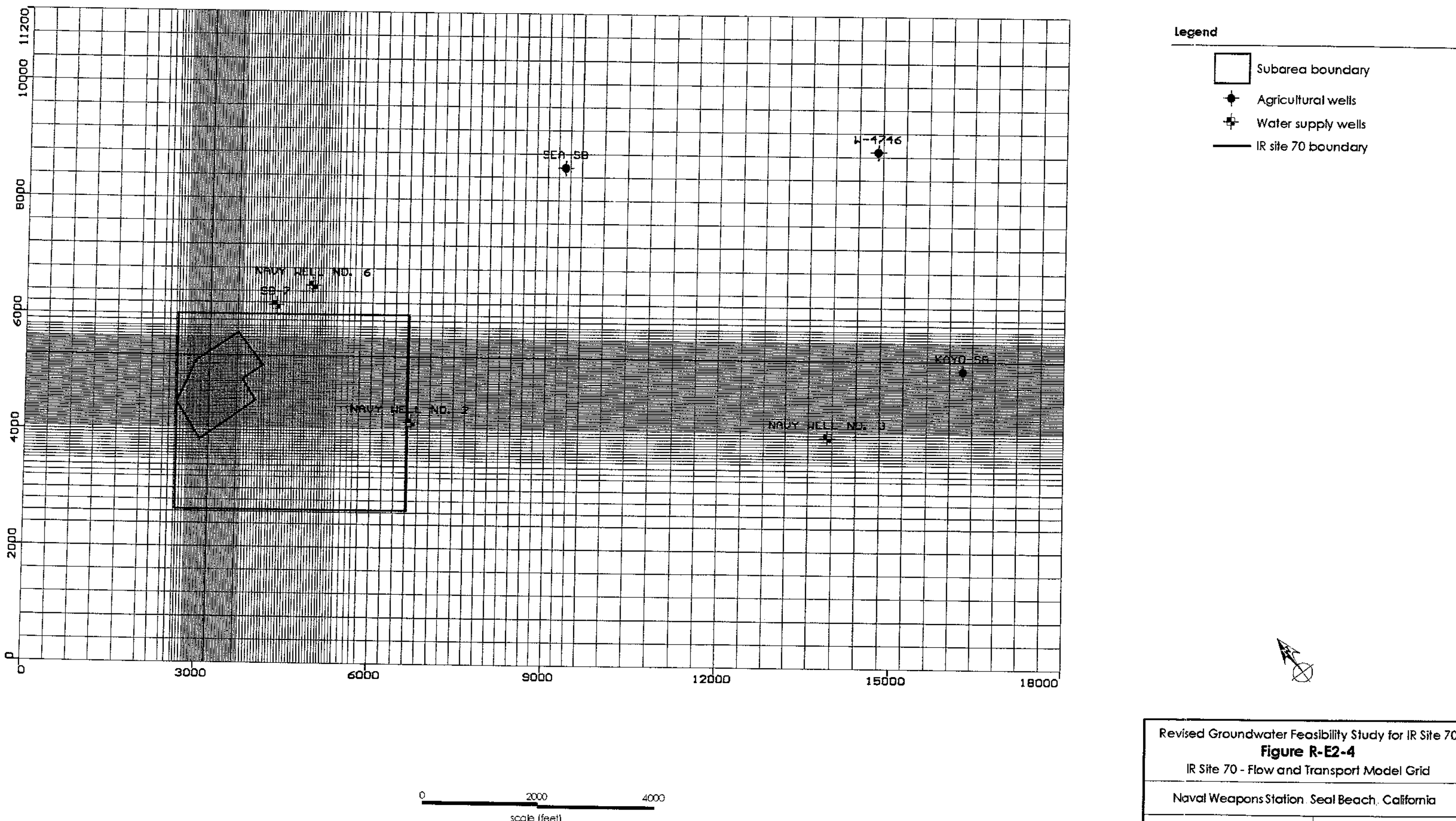
The model horizontal dimensions are dictated by the need to include the nearest water supply wells that appear to be affecting the groundwater gradients within the plume. The locations of these wells, SEA-SB, W-4746, and KAYO-SB, are shown on Figure R-E2-4. Other water supply wells are located north and west of IR Site 70, but appear to have less of an effect on the plume, based on the current configuration of the plume and the recent hydraulic gradient determined from water levels in plume monitoring wells. The three supply wells noted above are included as hydraulic sinks within the model. These wells extend approximately 400 feet bgs, and the assumption is made that 25 percent of the pumped groundwater is derived from the second sand unit, with the remainder of the pumped quantity coming from coarse sands below the deep clay unit. Navy Water Wells Nos. 2, 3 and 6 are inactive. The City of Seal Beach Well SB-7 has not been used for water supply for 14 years (and perhaps for 18 years), although the well is functional and could be used for an emergency (Bramlett 2000). Because these wells are not currently affecting the plume, pumping rates were not assigned for the flow model.

The following pumping rates and usage periods were assumed for the flow model.

- **KAYO-SB**. A pumping rate of 600 gpm was measured in July 1999 and is reportedly used for 9 months per year; an assumption of 150 gpm pumping rate from the second sand unit for 9 months per year is made for purposes of the modeling.

- **W-4746**. A pumping rate of 500 gpm was measured in July 1999 and is reportedly used for 12 months per year; an assumption of 125 gpm pumping rate from the second sand unit for 12 months per year is made for purposes of the modeling.

- **SEA-SB**. A pumping rate of 650 gpm was measured in July 1999 and is reportedly used only 3 months per year, which corresponds to 162.5 gpm for 3 months; to simplify the model simulations, an assumption of an equivalent usage of 50 gpm for 9 months per year is made for purposes of the modeling.



Revised Groundwater Feasibility Study for IR Site 70
Figure R-E2-4
IR Site 70 - Flow and Transport Model Grid

Naval Weapons Station, Seal Beach, California

GeoSyntec Consultants

Date: 7/12/04
File No: 127R4593
Job No: HY0888
Rev No: A

For the model simulations, a high pumping period (325 gpm from the second sand unit) at the three agicultural wells is assumed for 9 months each year, and a low pumping period (125 gpm) is assumed for 3 months each year.

Seasonal recharge was applied to the upper model layer in the area east of Kitts Highway, in an attempt to obtain a seasonal reversal of the horizontal hydraulic gradient in the interbedded unit. Recharge was assumed to occur for 3 months during the winter season, when precipitation is highest and evapotranspiration is lowest. A recharge rate equivalent to 2 inches per year was assumed, which is approximately 10 percent of the annual precipitation.

The vertical grid for the model is composed of ten layers to represent the six hydrostratigraphic units from the shallow clay unit to the deep clay unit, as shown in Figure E2-1. The bottom of the deep clay unit is a no-flow boundary for the model. The surficial soils and shallow clay unit are combined into a single model layer. The interbedded unit is divided into two model layers. The first sand unit is divided into three model layers. The shell horizon is a separate layer. The second sand unit comprises the next two model layers. Finally, the deep clay unit makes the lowest model layer. The layer depths, thicknesses, and elevations are presented in Figure E2-1.

The model sides are treated as general-head boundaries for all layers above the bottom layer. Constant-head boundaries are assigned to the sides of the bottom layer. The initial heads at the boundaries were assigned to provide a horizontal hydraulic gradient of approximately 0.0015, based on water level measurements within the plume area, and to allow a downward head difference of approximately 1 to 3 feet between the interbedded unit and the first sand unit.

R-E2.2.3 Flow Model Properties

The flow model layer properties required for the model simulations are the following:

- Horizontal hydraulic conductivity;
- Vertical hydraulic conductivity;
- Specific yield (for the water-table layer and layers in which pumping may cause water levels to drop below the top layer, i.e., layers 1 and 2); and
- Specific storage (for confined layers, layers 2 through 10).

These property values used in the modeling simulations are summarized in Table R-E2-2. Property values assumed by Bechtel (2002) were used for purposes of simulating Alternative 11. This section describes the basis for the selected property values, as described in the FS (BNI, 2002).

Table R-E2-2 also includes model layer elevation and thickness, vertical anisotropy ratio, vertical conductance, transmissivity, total porosity, effective porosity, and storage coefficient. Model layer elevations and thicknesses are based largely upon the continuous core logs for EW-70-02 (near pumped well EW-70-01) and CC-70-03, but also upon the cross-sections in the ERSE Report. Transmissivity is the thickness multiplied by the horizontal hydraulic conductivity. Total porosity and effective porosity are provided for comparison to specific yield values. The storage coefficient is the specific storage multiplied by layer thickness.

Layer properties are based upon test data as available. Test data include the pumping test and pilot test at EW-70-01, the step test at EW-70-02, slug tests in monitoring wells, and geotechnical laboratory tests. Analysis of the 3-month pilot test and 5-day pumping test at EW-70-01 provides an estimate of transmissivity and storage coefficient for the upper portion of the interbedded unit (Technical Memorandum Nos. 4 [BNI, 1999b] and 5 [BNI, 1999c]). The step test at EW-70-02 provided data for an estimate of transmissivity and storage for the upper portion of the first sand unit (Technical Memorandum No. 4, BNI, 1999b). Slug tests, providing a measure of hydraulic conductivity, have been performed in monitoring wells in the interbedded unit, first sand unit, shell horizon and second sand unit (Table E2-5). Remaining properties required for the model are assumed, based upon literature values where appropriate, and adjusted through model calibration as described in previous reports that included modeling analysis for IR Site 70 (ERSE Report [BNI, 1999a] and Technical memorandum Nos. 4 [BNI, 1999b] and 5 [BNI, 1999c]). Further discussion of the property assumptions is provided below.

The horizontal hydraulic conductivities for the shallow clay unit (model layer 1) and the deep clay unit (model layer 10) are assumed to be 1×10^{-6} centimeters per second (cm/s). (The thin unit of unsaturated surficial soils is neglected in the flow model). Massive clay typically has a hydraulic conductivity of less than 1×10^{-7} cm/s (U.S. Bureau of Reclamation, 1981). Silt, clay, and mixtures of sand, silt, and clay typically have hydraulic conductivities ranging from 1×10^{-4} cm/s to 1×10^{-7} cm/s (U.S. Bureau of Reclamation, 1981). The geologic logs indicate the shallow clay unit has low plasticity, a trace of caliche nodules, and a trace of fine-grained sand, and can include sandy clay, sandy silt, and silty sand, although clay is predominant. The shallow clay unit is not considered massive clay, but a value of 1×10^{-6} cm/s reflects the predominance of clay.

The deep clay unit is commonly silty clay with a trace of sand, and can include clayey silt, sandy silt, and silty sand, although clay appears predominant. The deep clay unit is also not considered massive clay, but a value of 1×10^{-6} cm/s reflects the predominance of clay.

The horizontal hydraulic conductivity for the upper portion of the interbedded unit (model layer 2) is based on the pumping test results for EW-70-01, where the transmissivity was determined to be 0.1 ft^2/min. Based on a saturated thickness of 15 feet, as indicated by continuously cored EW-70-02, the hydraulic conductivity is 0.036 cm/s.

The horizontal hydraulic conductivity of the lower portion of the interbedded unit (model layer 3) is assumed to be 5×10^{-6} cm/s. This portion of the interbedded unit includes a variable interbedded silt and clay and sometimes sand. Because the fine-grained portion dominates this model layer but silt and sand are included, the value selected is biased to the upper range for mixtures of sand, silt, and clay (U.S. Bureau of Reclamation 1981).

The horizontal hydraulic conductivity for the upper portion of the first sand unit (model layer 4) is based on the numerical model calibration for Step Test No. 2 at EW-70-02 (Technical Memorandum No. 4, BNI, 1999b). The slug test results at MW-70-04, located near EW-70-02, indicate a hydraulic conductivity of 0.0027 cm/s (Table E2-4). However, the step test is considered to provide a more reliable determination of hydraulic conductivity, and a value of 0.0056 cm/s was shown to provide a reasonable match between the model simulation and the test data.

The horizontal hydraulic conductivity for the middle and lower portion of the first sand unit (model layers 5 and 6), the shell horizon (model layer 7), and the second sand unit (model layers 8 and 9) are based on the geometric means of slug test results for monitoring wells. Four tests in the lower portion of the first sand unit (and partially screened in the shell horizon), at wells MW-70-07, MW-70-12, MW-70-13, and MW70-16, indicate an average hydraulic conductivity of 0.014 cm/s (Table E2-4). Three tests in the second sand unit, at wells MW-70-09, MW-70-14, and MW-70-15, indicate an average hydraulic conductivity of 0.024 cm/s (Table E2-4). The slug test results indicate a general increase in hydraulic conductivity with depth, as shown in Figure E2-5, which is consistent with the increasing proportions of medium- and coarse-grained sand.

The shell horizon is described in the ERSE Report as consisting of typically fine- to coarse-grained sand, locally fine to medium grained, with shell content ranging from a trace to over 50 percent. For the model simulations, a horizontal hydraulic conductivity equivalent to the second sand unit is assumed, based on the field geologist's observations of similar percentage of coarse-grained sand.

The vertical hydraulic conductivity is generally assumed to be one tenth of the horizontal hydraulic conductivity. However, exceptions were made for the interbedded unit, shell horizon, and second sand unit. For the lower fine-grained portion of the interbedded unit (model layer 3), a ratio of 1:50 is assumed for vertical to horizontal conductivity. This higher ratio is considered justified because of the mix of silts and clays, with the clay controlling the vertical hydraulic conductivity and silt controlling the horizontal hydraulic conductivity. For the shell horizon and the lower portion of the second sand unit (model layers 7 and 9), a ratio of 1:5 is assumed for vertical to horizontal hydraulic conductivity. The lower ratio is considered justified because of the significant lack of clay lenses in these layers. Vertical to horizontal anisotropy ratios typically range between 1 and 100 (Marsily 1986).

The anisotropy ratios selected for the model layers are intended to reflect the observed stratigraphy and the measured head differences between layers. A significant head difference exists between the interbedded unit and the first sand unit, and a negligible head difference exists between the lower portion of the first sand unit and the second sand unit. Head differences between the interbedded unit and the upper portion of the first sand unit are typically 1 to 3 feet, while head differences between the lower portion of the first sand unit and the second sand unit are typically 0.0 to 0.3 feet (Table E2-6). The anisotropy ratios also reflect the higher degree of interbedded fine-grained materials in the upper units compared to a lower degree of interbedded fine-grained materials in the deeper units. The anisotropy ratios are difficult to estimate, but the flow model calibration indicates a ratio of 1:10 to 1:50 is required for the upper model layers. These ratios provide a reasonable match to the observed water level responses during the pumping test at EW-70-01 and to the observed downward gradient that occurs throughout the year.

The total porosity values shown in Table R-E2-2 are averages for the model layers based upon geotechnical laboratory test results (Table E2-5). The shallow clay unit (model layer 1) has an average porosity of 43 or 44 percent, based on 9 or 26 samples, depending whether vadose zone clay samples are included. The upper portion of the interbedded unit (model layer 2) has a value of 40 percent based on three samples, and the lower portion of the interbedded unit (model layer 3), dominated by fine-grained material, is assumed the same as the shallow clay unit. The value for the upper portion of the first sand unit (model layer 4) is 37 percent based on six samples. The value used for the middle and lower portions of the first sand unit (model layers 5 and 6) is 33 percent based on six samples. The value for the second sand unit (model layers 8 and 9) is 36 percent based on seven samples. This value is also assumed for the shell horizon. For the deep clay unit (model layer 10), the total porosity is assumed to be the same as the shallow clay unit. Effective porosity values are difficult to estimate, but must be less than total porosity. The effective porosity values are assumed to be 83 percent of total porosity, based on the mean grain-diameter relationship for porosity components (Marsily 1986, and Technical Memorandum No. 5, Table I-2 [BNI, 1999c]).

Assumed values for specific yield are based on typical values for various grain sizes. A specific yield of 0.02 to 0.07 is typical for clay and sandy clay, 0.08 is typical for silt, 0.21 is typical for fine sand, and 0.26 is typical for medium sand (Johnson, 1967). A value of 0.04 was selected for the shallow clay unit and deep clay unit, which are predominantly clay. A value of 0.06 was selected for the lower portion of the interbedded unit, considered a mixture of clay and silt. A value of 0.21 was selected for the upper portion of the interbedded unit and the first sand unit as being typical for fine sand. A value of 0.26 was selected for the shell horizon and the second sand unit, where medium sand appears to be dominant.

Specific storage is generally 0.0001 per foot (ft^{-1}) or less (Fetter, 1994), and the storage coefficients for confined aquifers typically range from 0.005 to 0.00005 (Freeze and Cherry 1979) or 0.001 to 0.00001 (Driscoll 1986). For the shallow clay unit (unconfined), the storage coefficient is equal to the specific yield (Driscoll 1986). For the upper portion of the interbedded unit, the storage coefficient was determined from the pilot test data to be 0.004 (Technical Memorandum No. 5, BNI, 1999c), resulting in a specific storage of 0.00027. The specific storage value for model layers 3 through 10 is assumed to be 0.00001, a median value within the typical range given above by Freeze and Cherry (1979) and Driscoll (1986).

R-E2.2.4 Solute Transport Model Properties

The layer properties required for the transport model simulation include dispersivity, soil/water distribution coefficient, soil bulk density, effective porosity, and degradation rate. Table R-E2-3 summarizes the property values used in the modeling simulations. This section describes the basis for the selected property values.

Effective porosity values are those specified in Table R-E2-2 for the flow model, and soil bulk density is derived from laboratory tests on soil samples from IR Site 70 (Table E2-5 [BNI, 2002]).

Dispersivity values are based on the calibration results for the transport model described in the ERSE Report, where the longitudinal dispersivity was determined to be 2.5 percent of the travel distance, the transverse/longitudinal dispersivity ratio was 0.1, and the vertical/longitudinal dispersivity ratio was 0.025.

The distribution coefficient (K_d) is based upon the equation $K_d = K_{oc} \times f_{oc}$ (Marsily 1986), where K_{oc} is the organic carbon distribution coefficient, and f_{oc} is the fraction of organic carbon in soil. The fraction of organic carbon is derived from laboratory tests on soil samples from IR Site 70 (Table E2-7), and the K_{oc} value is derived from the literature. The f_{oc} values are high near the surface, but decrease significantly below 10 feet bgs, as shown on Figure E2-6 (BNI, 2002).

Fate and transport properties for the primary plume contaminant TCE and daughter products cis-DCE, VC, ethene, and chloride are derived from representative values provided in the literature (Table E2-8 [BNI, 2002]). Properties required for the transport model include the organic carbon-to-water partitioning coefficient (K_{oc} – see Table E2-8 for assumed values for each constituent) and the aqueous diffusion coefficient (D_e), which is 8.3×10^{-6} square centimeters per second (Cohen and Mercer 1993).

For the simulations of remedial Alternative 11, degradation rates of TCE, cisDCE, VC, and ethene are included for all units, with variable rates corresponding to zones where bioactivity has been stimulated through the injection of emulsified vegetable oil and a dechlorinating culture, and zones where natural attenuation is occurring. For the bioactive zones, a 4-day half life was assumed for all compounds. Typical half-lives observed in biostimulated zones are in the range of a few hours to a few days; therefore, a half-life of 4 days represents a conservative estimate. For the natural attenuation zones, degradation half-lives of the various compounds were taken to be mean values quoted in Suazez and Rifai (1999; see Table R-E2-3 for details).

R-E2.3 MODEL SIMULATIONS

Section R-E2.4 of the RFS discusses only Alternative 11. A discussion of the model simulations of Alternatives 6 to 10 is included in the original FS (BNI 2002). Section R-E2.4.1 discusses the biobarrier layout required for source and plume bioremediation for Alternative 11. Section R-E2.4.2 describes the initial conditions for the flow and transport simulations. Section R-E2.4.3 presents the simulated plume concentrations. Section R-E2.4.4 discusses the simulated mass removed. Finally, Section R-E2.4.5 provides a summary of the relative effectiveness of the alternatives.

R-E2.3.1 Alternative 11 - Biobarrier Layout

The number of biobarriers and barrier spacing for plume treatment for Alternative 11 was originally estimated targeting a five-year travel time between barriers and assuming an average groundwater velocity of 100 ft/year in the upper and lower sand units. The biobarriers were represented in the model as zones with higher degradation rate constants. Within the source area, a uniform grid of wells on 25 ft centers was assumed – this was represented as a cubic zone of enhanced biodegradation rate constants in the 200 by 300 ft area containing TCE concentrations greater than 10,000 μg/L. One additional biobarrier is located to the north of the source area to contain any mass flux out of the source area during seasonal reversals of the groundwater gradient.

Due to limitations in the modeling code, residual DNAPL is not represented in the transport model. The RT3D modeling code does not include multiphase modeling kinetics, and no information is available regarding the mass or distribution of DNAPL present in the subsurface.

R-E2.3.2 Initial Conditions for Alternative 11

This section provides a description of the initial heads and initial concentrations used in the modeling simulations for remedial Alternative 11.

As noted in Section E2.2.1, the following characteristics for water levels have been observed.

- Water levels fluctuate seasonally by 5 feet in the interbedded unit, first sand unit, and second sand unit (Technical Memorandum No. 5, [BNI, 1999c] Appendix F).
- Head differences between the interbedded unit and first sand unit are typically 1 to 3 feet downward.
- Head differences between the first and second sand units range form 0 to 0.3 foot downward.
- Seasonal fluctuations that occur in all hydrostratigraphic units likely result from seasonal variation in water well usage at agricultural wells and, perhaps, at more distant municipal wells.

Furthermore, other characteristic of the head differences between specific hydrostratigraphic units and seasonal fluctuations include the following:

- Head differences between units are lower during winter periods of high water levels (corresponding to reduced agricultural well pumping) compared to early autumn periods of low water levels.
- The seasonal change in the head difference between any two specific hydrostratigraphic units is less than the total seasonal fluctuation in water levels for either unit.
- The seasonal change in water levels appears to occur simultaneously in all hydrostratigraphic units.

The average simulated water levels, horizontal hydraulic gradients, and vertical head differences, are sufficiently similar to measured data within the IR Site 70 plume area that plume migration can be reasonably simulated with respect to these hydraulic parameters. The simulated horizontal hydraulic gradient was approximately 0.0010, compared to measured gradients of approximately 0.0010 to 0.0015. The simulated head differences between model layers 2 and 4 is approximately 1 to 2 feet downward, depending upon the period of simulated seasonal agricultural well pumping, compared to typically measured values of 1 to 3 feet downward. The simulated head differences between model layers 6 and 9 is negligible, compared to measured values of 0 to 0.3 foot. The simulated seasonal cyclic fluctuation in potentiometric heads was approximately 1 foot, compared to the measured fluctuation of 5 feet during 1998 to 1999.

Difficulty was encountered with model simulations in matching the range of seasonal fluctuations in water levels and head differences. Simulated fluctuations were less than half of the observed fluctuations. Although an improvement in matching seasonal fluctuations of heads and head differences would provide higher confidence in the model, the existing model is deemed acceptable for the purpose of comparing long-term remedial alternatives because a reasonable match was obtained for average water levels and average vertical head differences, as indicated earlier in this section.

The simulated initial potentiometric heads for model layers 2 and 6 are shown in Figures R-E2-12A through R-E2-12D. Potentiometric heads are shown for these two layers for two periods during each year: a period of high pumping from agricultural wells and another period of low pumping from agricultural wells, as discussed in Section R-E2.3.2. The simulated heads for model layers between 4 and 9 are all similar to model layer 6 and are not individually shown. Simulated heads for model layers 1, 3, and 10 are not shown because these are fine-grained layers, and measured data on heads are not available for useful comparison.

Seasonal reversal of the horizontal hydraulic gradient within the shallow plume (i.e., within the interbedded unit) was not simulated, although cyclic fluctuations in agricultural well pumping and recharge in agricultural areas were included in the model. Other influences on shallow water levels are likely present.

Initial concentrations for the model layers are shown in Figures R-E2-14A through R-E2-14D. As shown in these figures, similar concentration distributions were used for two or more model layers. Model layers 1, 2, and 3 were assumed to have similar concentrations. Model layers 4, 5, 6 and 7, and 8 and 9 were respectively assumed to have similar concentrations. Model layer 10 was assumed to have negligible concentrations. Areas of TCE concentrations interpreted to be less than 5 μg/L are not included in the model because of the difficulty in determining extent for some areas and because of the nominal increase in mass.

Few measured concentrations in the shallow clay are available (three samples at less than 20 feet bgs) because of the difficulty in obtaining groundwater samples from the fine-grained material. Concentrations reported for vadose zone soil samples from the shallow clay suggest that the saturated shallow clay will have lower concentrations than the interbedded unit, in which case the assumed initial concentrations will have been overestimated.

R-E2.3.3 Simulated TCE Concentrations

Before the modeling simulations were begun, a decision was made to limit the simulation periods to 30 years because of increasing uncertainty of predictions for long periods, although in a few model layers the simulated TCE concentrations may still exceed 5 μg/L.

The concentration contours are provided to demonstrate treatment of the plume and source in Alternative 11 and support the evaluation of relative effectiveness among the alternatives. The simulated concentrations for Alternatives 6 through 10 are presented in the original FS (BNI 2002) for 10-year intervals.

Simulated concentrations are shown in Figures R-E2-44 through R-E2-52 (model layers 1 through 9) for Alternative 11. Times of 6 years and 15 years are shown as these correspond to the maximum targeted duration of plume (6 years) and source treatment (15 years).

R-E2.3.4 Simulated TCE Mass Removed

The simulated mass removed for *in situ* bioremediation for Alternative 11 is shown in the mass balance summary presented in Table R-E2-9, which includes the initial mass distribution by layer and the final mass disposition after termination of treatment (i.e., 50 years for Alternatives 6 through 10, and 15 years for Alternative 11).

The mass removed by *in situ* bioremediation has been estimated by subtracting the initial mass present from the end mass, calculated using a volume-weighted approach based on the final concentration contours. The MT3D mass budget summary could not be used to estimate mass removal as RT3D was used as the reactive transport module in place of MT3D; RT3D does not contain the mass budget summary capability. While the volume-weighted approach does not provide the same level of accuracy as the MT3D mass budget summary, it does provide an adequate estimate for evaluating mass removal effectiveness.

It should be noted that, due to the assumption of a constant concentration boundary condition in the source area over the first 15 years, the mass estimates in layer 1 are likely overestimated. As stated in Section R-E2.4.2, measured TCE concentrations and indications of significant presence of DNAPL mass in the shallow clay layer are minimal in number; therefore, results in layer 1 are not likely to be representative of actual conditions.

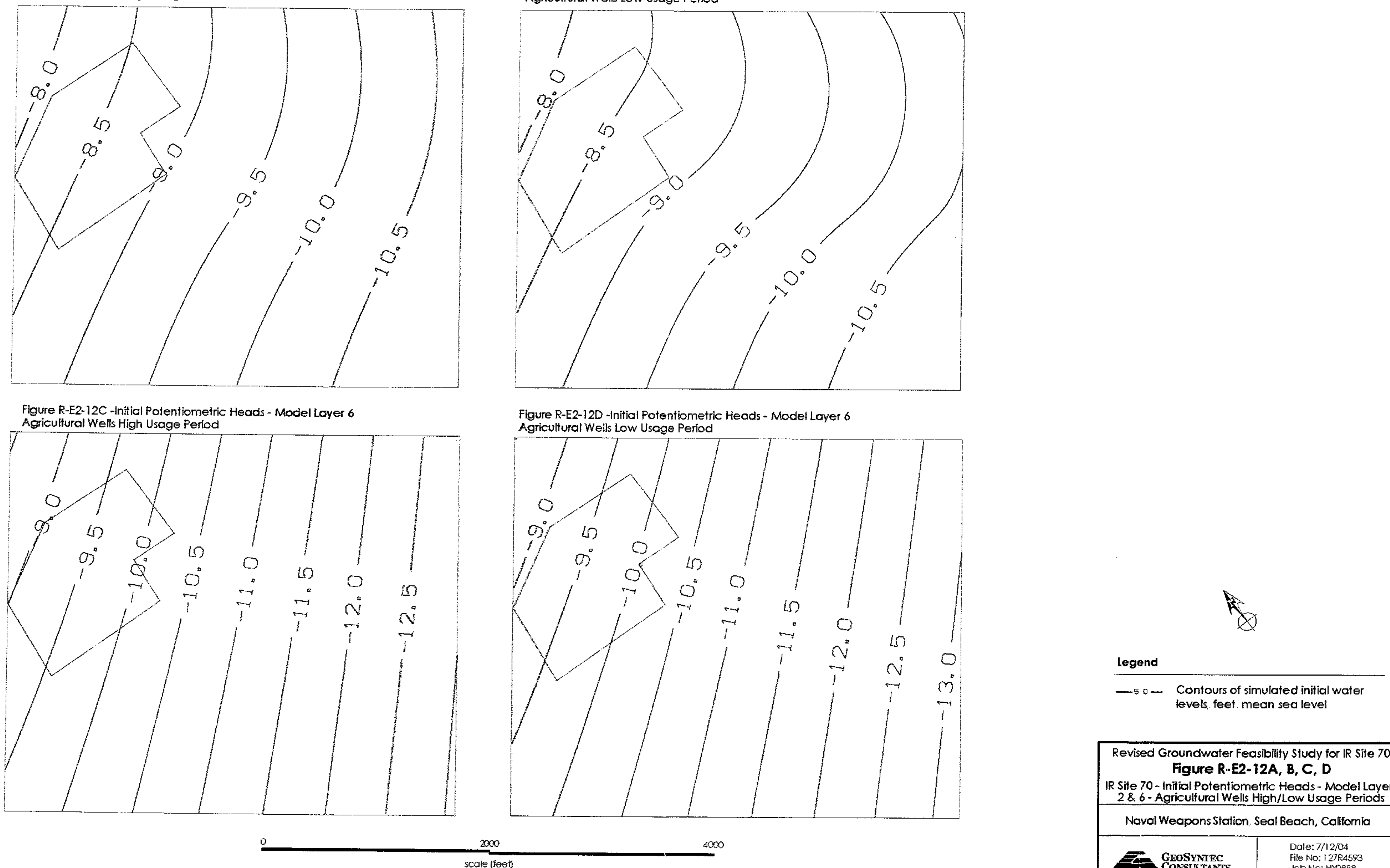
A comparison of mass removal effectiveness for the alternatives is summarized in the next section.

Figure R-E2-12A -Initial Potentiometric Heads - Model Layer 2
Agricultural Wells High Usage Period

Figure R-E2-12B -Initial Potentiometric Heads - Model Layer 2
Agricultural Wells Low Usage Period

Figure R-E2-12C -Initial Potentiometric Heads - Model Layer 6
Agricultural Wells High Usage Period

Figure R-E2-12D -Initial Potentiometric Heads - Model Layer 6
Agricultural Wells Low Usage Period



Revised Groundwater Feasibility Study for IR Site 70
Figure R-E2-12A, B, C, D
IR Site 70 - Initial Potentiometric Heads - Model Layers 2 & 6 - Agricultural Wells High/Low Usage Periods
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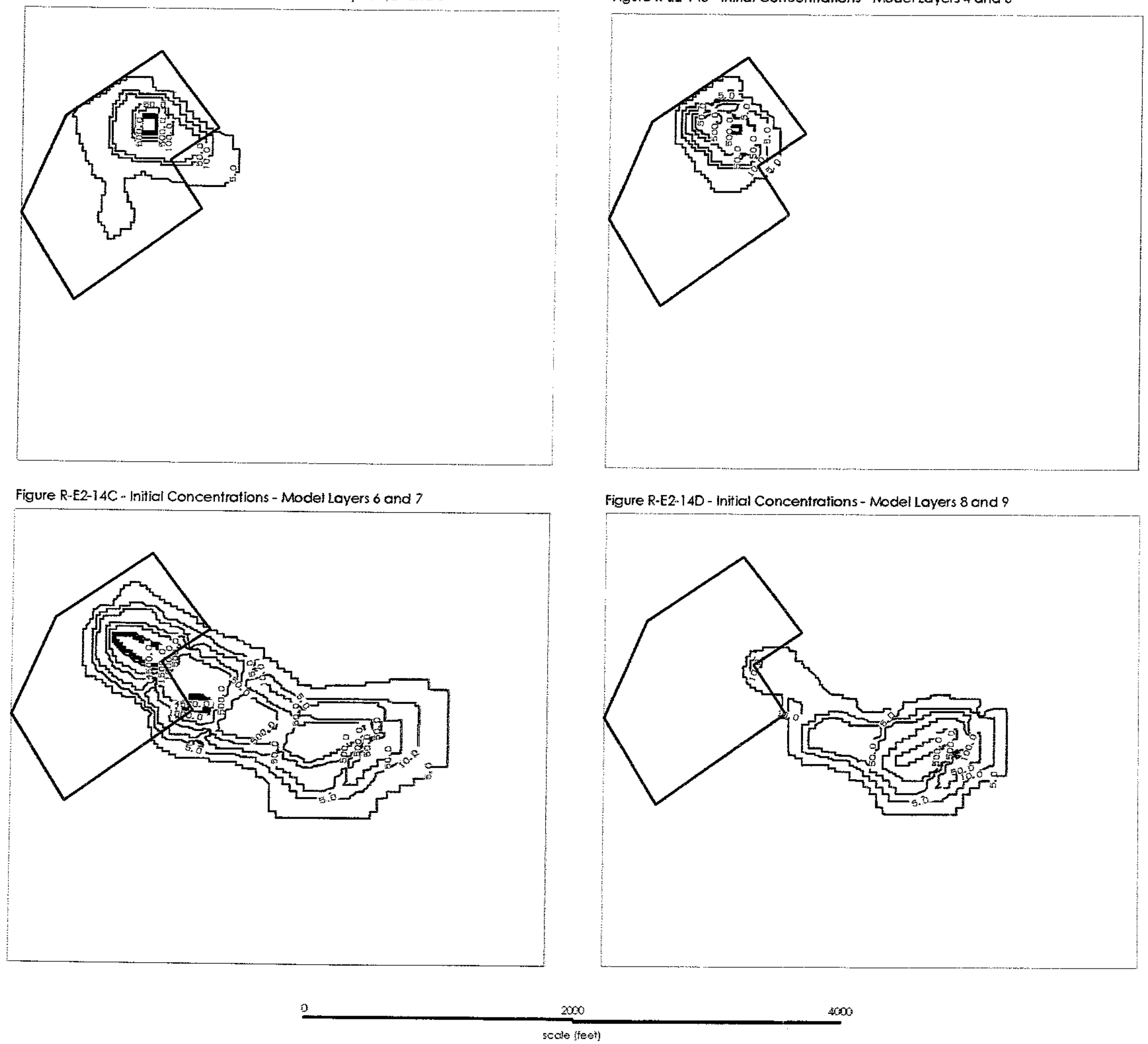
GeoSyntec Consultants
Date: 7/12/04
File No: 127R4593
Job No: HY0888
Rev No: A

Figure R-E2-14A - Initial Concentrations - Model Layers 1,2 and 3

Figure R-E2-14B - Initial Concentrations - Model Layers 4 and 5

Figure R-E2-14C - Initial Concentrations - Model Layers 6 and 7

Figure R-E2-14D - Initial Concentrations - Model Layers 8 and 9



Legend

5.0 Contours of initial TCE concentrations, in micrograms per liter (µg/L)

Revised Groundwater Feasibility Study for IR Site 70

Figure R-E2-14A, B, C, D

IR Site 70 - Initial Concentrations - Model Layers 1 through 9

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Figure R-E2-44A - Simulated Concentrations for Alternative 11 - Model Layer 1 - 6 Years

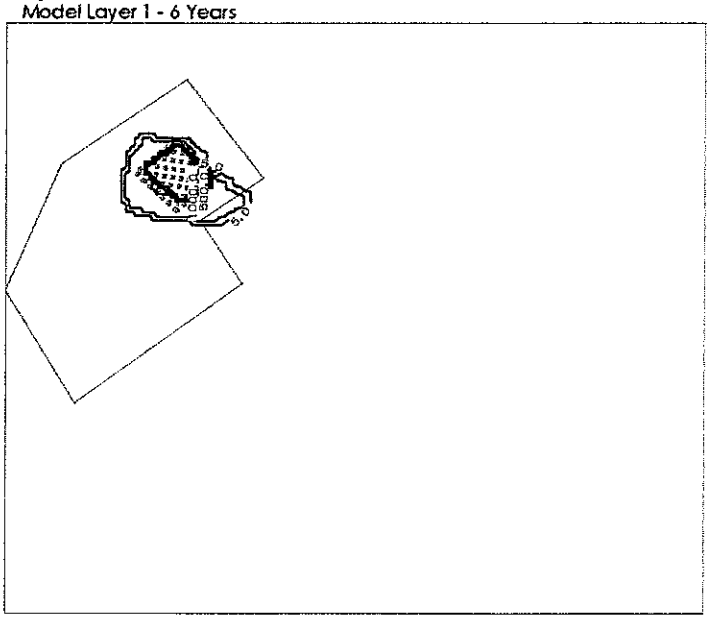
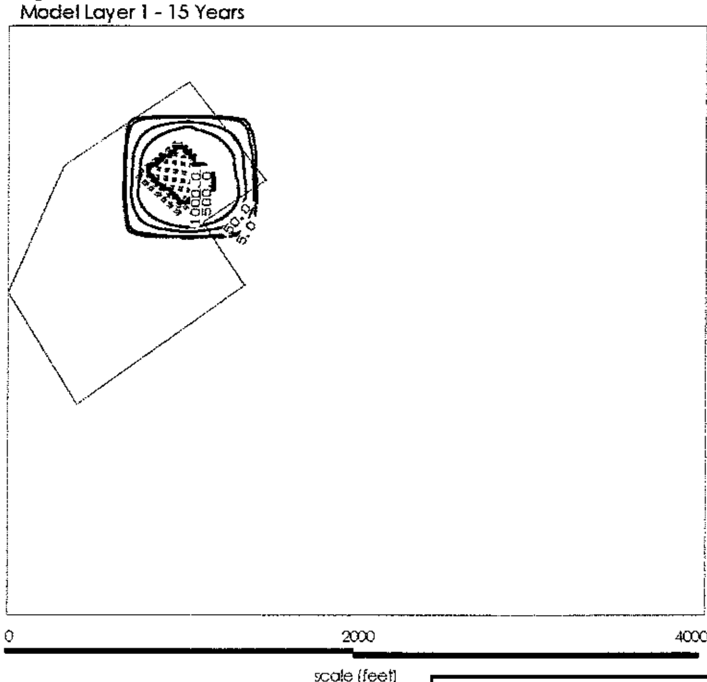


Figure R-E2-44B - Simulated Concentrations for Alternative 11 - Model Layer 1 - 15 Years



Legend

—10.0— Contours of simulated TCE concentrations, in micrograms per liter (µg/L)

Source Area Treatment

Revised Groundwater Feasibility Study for IR Site 70

Figure R-E2-44A, B

IR Site 70 - Simulated Concentrations for Alternative 11 - Model Layer 1 - 6 and 15 Years

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File No: 127R4593
Job No: HY0888
Rev No: A

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Figure R-E2-45A - Simulated Concentrations for Alternative 11 - Model Layer 2 - 6 Years

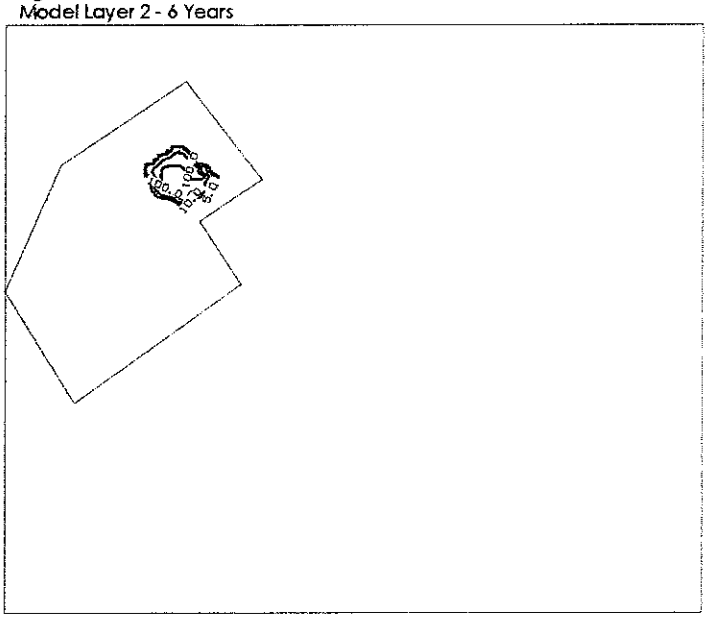
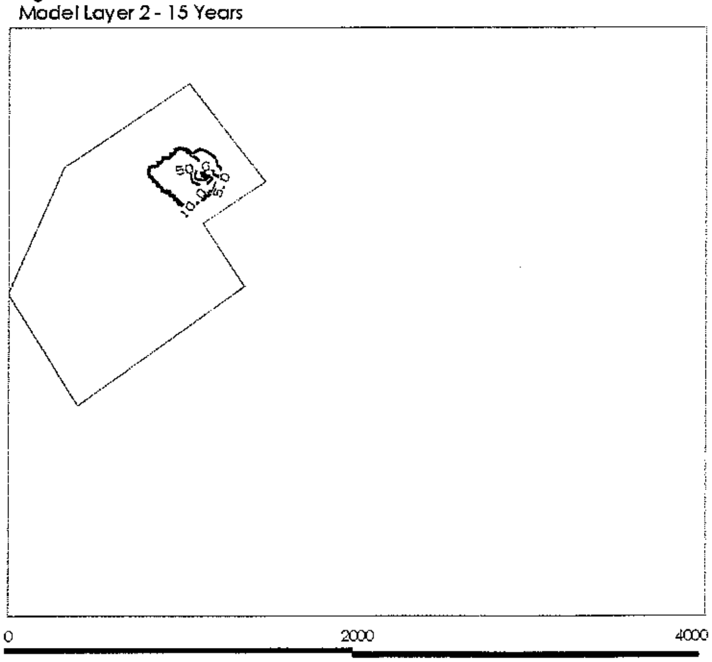


Figure R-E2-45B - Simulated Concentrations for Alternative 11 - Model Layer 2 - 15 Years



Revised Groundwater Feasibility Study for IR Site 70

Figure R-E2-45A, B

IR Site 70 - Simulated Concentrations for Alternative 11 - Model Layer 2 - 6 and 15 Years

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GeoSyntec Consultants

Date: 7/12/04
File No: 127R4593
Job No: HY0888
Rev No: A

Legend

—10.0— Contours of simulated TCE concentrations in micrograms per liter (µg/L)

Feasibility Study_E2-41A-B.ai

Figure R-E2-46A - Simulated Concentrations for Alternative 11 - Model Layer 3 - 6 Years

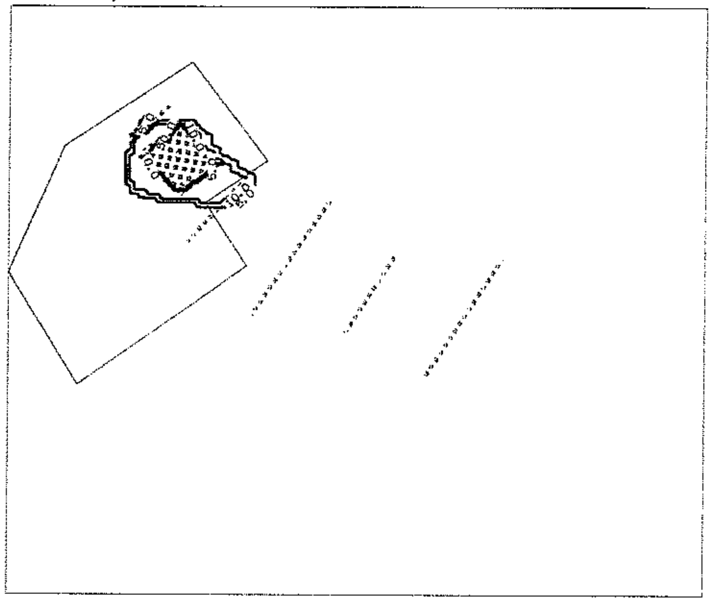
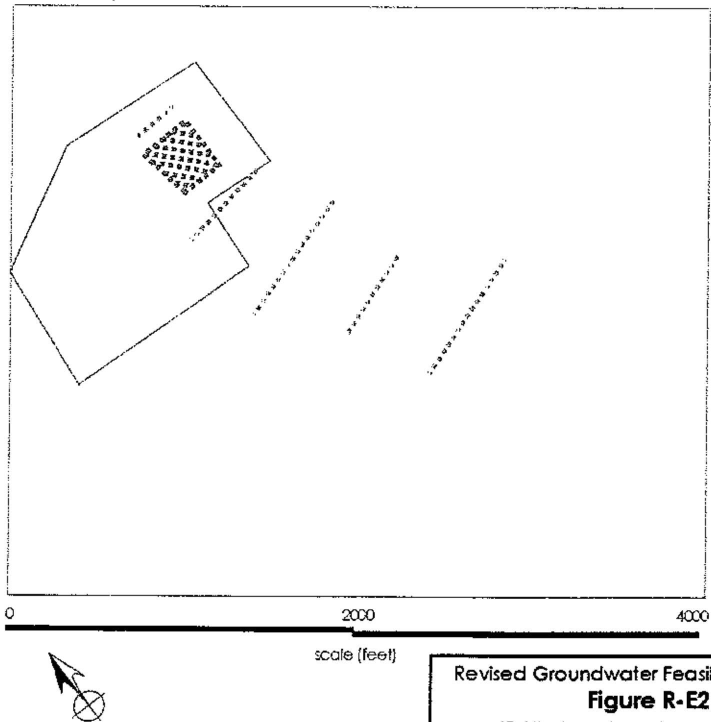


Figure R-E2-46B - Simulated Concentrations for Alternative 11 - Model Layer 3 - 15 Years



Legend

—10.0— Contours of simulated TCE concentrations, in micrograms per liter (µg/L)

Biobarrier Location

Source Area Treatment

Revised Groundwater Feasibility Study for IR Site 70

Figure R-E2-46A, B

IR Site 70 - Simulated Concentrations for Alternative 11 - Model Layer 3 - 6 and 15 Years

Naval Weapons Station, Seal Beach, California

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Date: 7/12/04
File No: 127R4593
Job No: HY0888
Rev No: A

Feasibility Study_E2-41A-7.ai

Figure R-E2-47A - Simulated Concentrations for Alternative 11 - Model Layer 4 - 6 Years

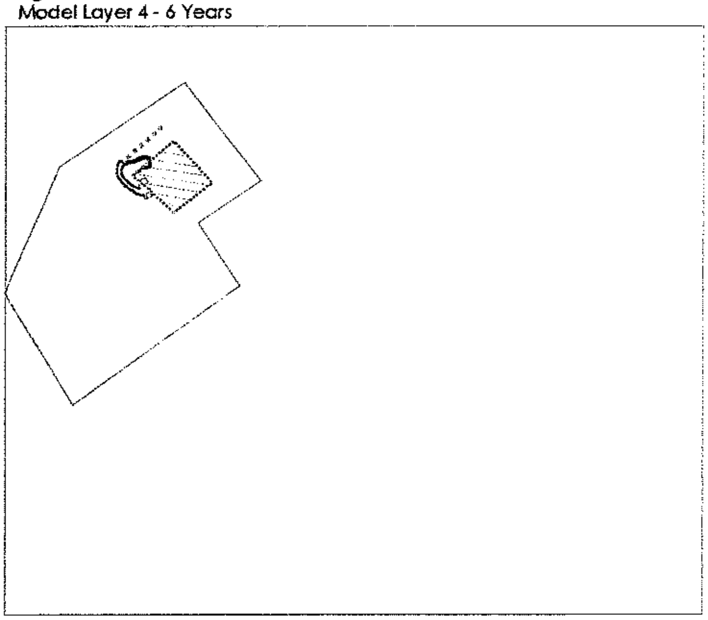
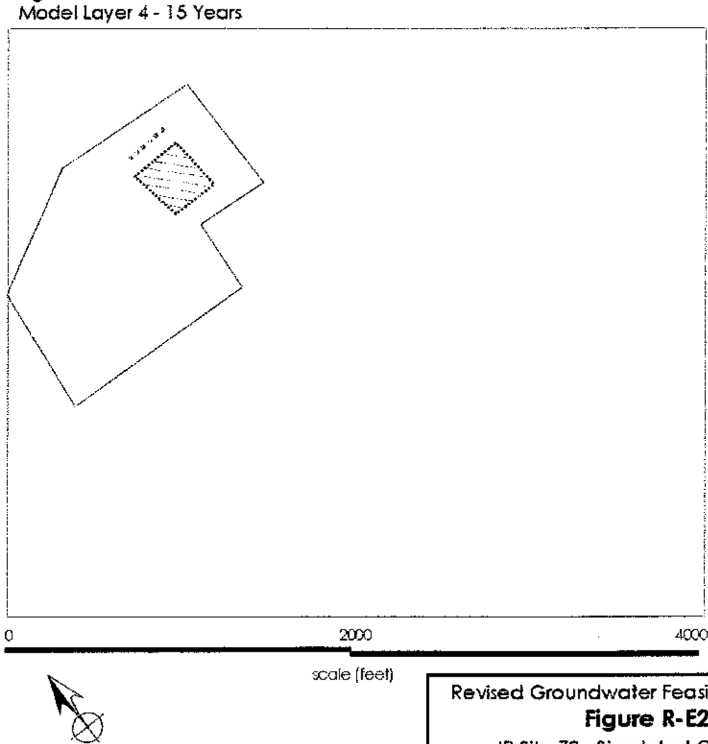


Figure R-E2-47B - Simulated Concentrations for Alternative 11 - Model Layer 4 - 15 Years



Legend

—10.0— Contours of simulated TCE concentrations, in micrograms per liter (µg/L)

Biobarrier Location

Source Area Treatment

Revised Groundwater Feasibility Study for IR Site 70

Figure R-E2-47A, B

IR Site 70 - Simulated Concentrations for Alternative 11 - Model Layer 4 - 6 and 15 Years

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Date: 7/12/04
File No: 127R4593
Job No: HY0888
Rev No: A

Feasibility Study_E2-41A-6.ai

Figure R-E2-48A - Simulated Concentrations for Alternative 11 - Model Layer 5 - 6 Years

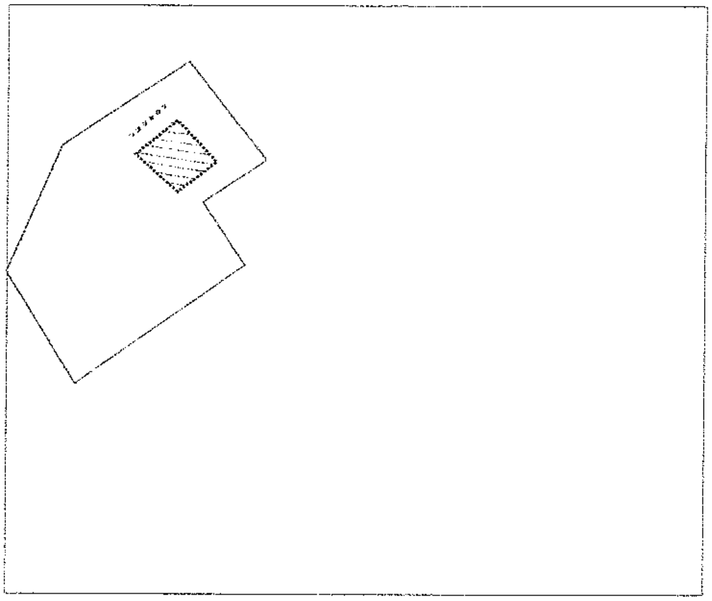
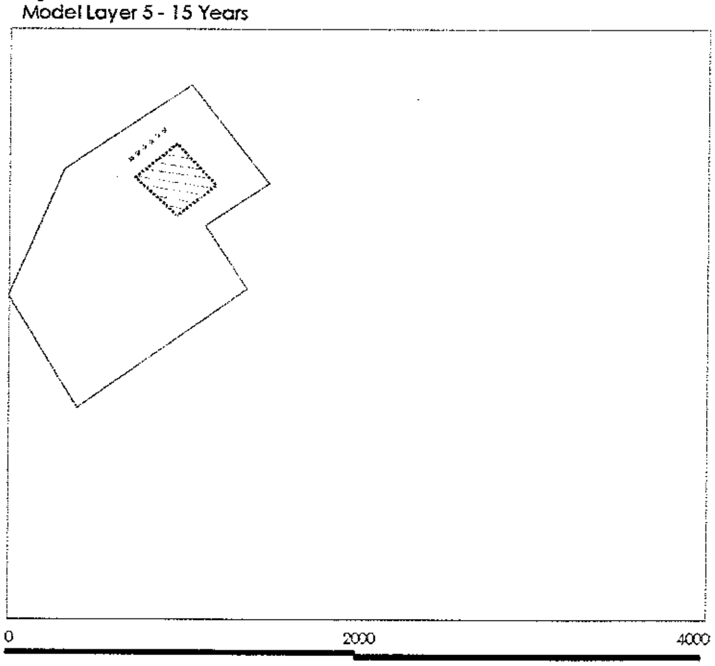


Figure R-E2-48B - Simulated Concentrations for Alternative 11 - Model Layer 5 - 15 Years



Legend

—10.0— Contours of simulated TCE concentrations, in micrograms per liter (µg/L)

Biobarrier Location

Source Area Treatment

Revised Groundwater Feasibility Study for IR Site 70

Figure R-E2-48A, B

IR Site 70 - Simulated Concentrations for Alternative 11 - Model Layer 5 - 6 and 15 Years

Naval Weapons Station, Seal Beach, California

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Date: 7/12/04
File No: 127R4593
Job No: HY0888
Rev No: A

Figure R-E2-49A - Simulated Concentrations for Alternative 11 -
Model Layer 6 - 6 Years

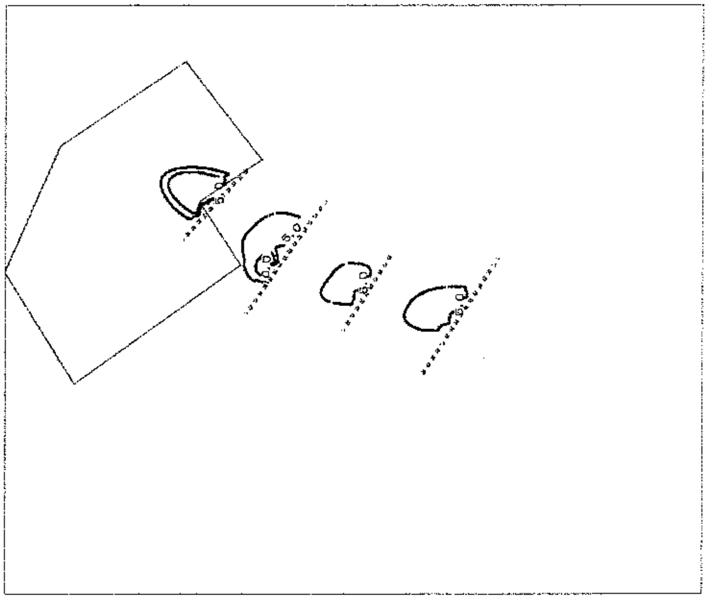
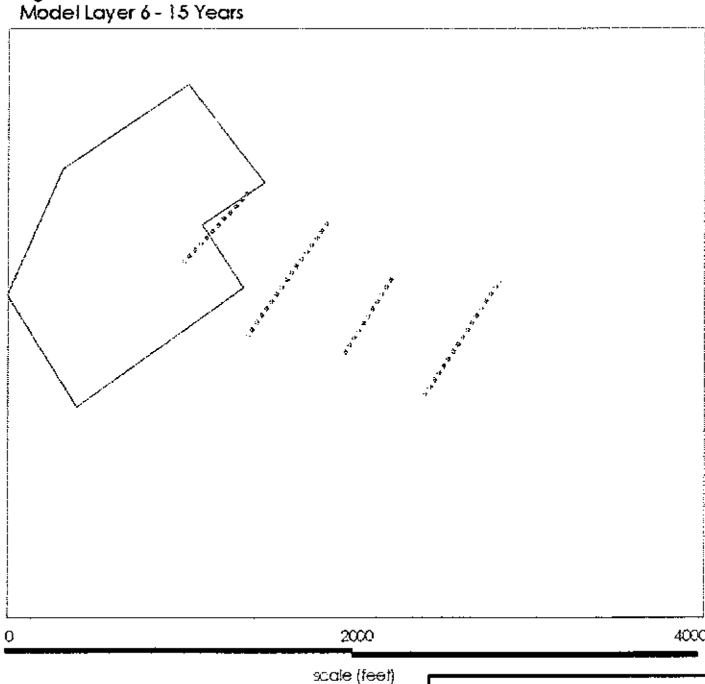


Figure R-E2-49B - Simulated Concentrations for Alternative 11 -
Model Layer 6 - 15 Years



Legend

—10.0— Contours of simulated TCE concentrations, in micrograms per liter (µg/L)

Biobarrier Location

Revised Groundwater Feasibility Study for IR Site 70

Figure R-E2-49A, B

IR Site 70 - Simulated Concentrations for Alternative 11 - Model Layer 6 - 6 and 15 Years

Naval Weapons Station, Seal Beach, California

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Date: 7/12/04
File No: 127R4593
Job No: HY0888
Rev No: A

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Figure R-E2-50A - Simulated Concentrations for Alternative 11 - Model Layer 7 - 6 Years

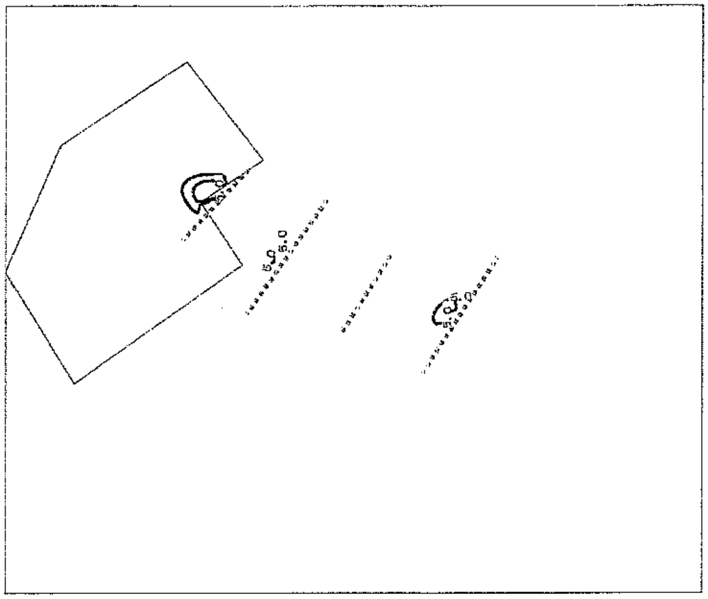
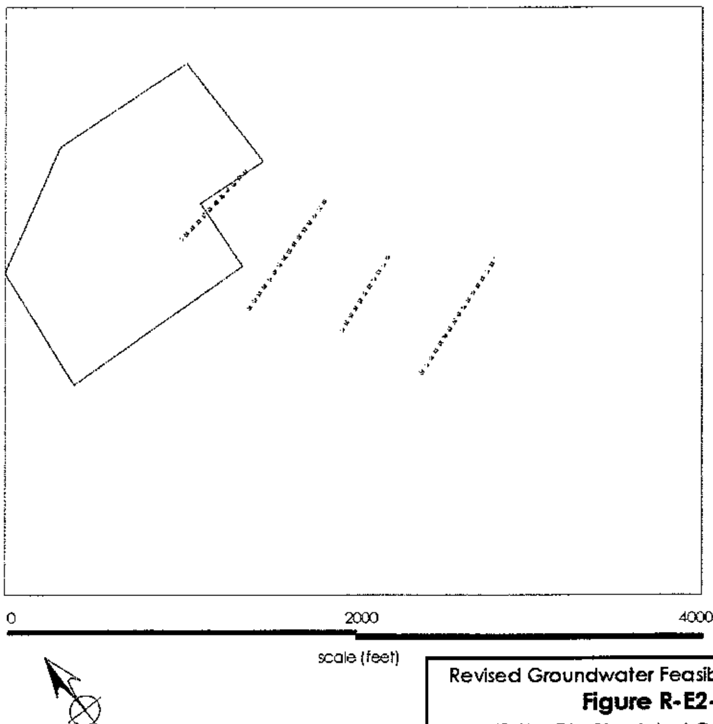


Figure R-E2-50B - Simulated Concentrations for Alternative 11 - Model Layer 7 - 15 Years



Legend

Contours of simulated TCE concentrations, in micrograms per liter (µg/L)

Biobarrier Location

Revised Groundwater Feasibility Study for IR Site 70

Figure R-E2-50A, B

IR Site 70 - Simulated Concentrations for Alternative 11 - Model Layer 7 - 6 and 15 Years

Naval Weapons Station, Seal Beach, California

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Job No: HY0888
Rev No: A

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Figure R-E2-51A - Simulated Concentrations for Alternative 11 - Model Layer 8 - 6 Years

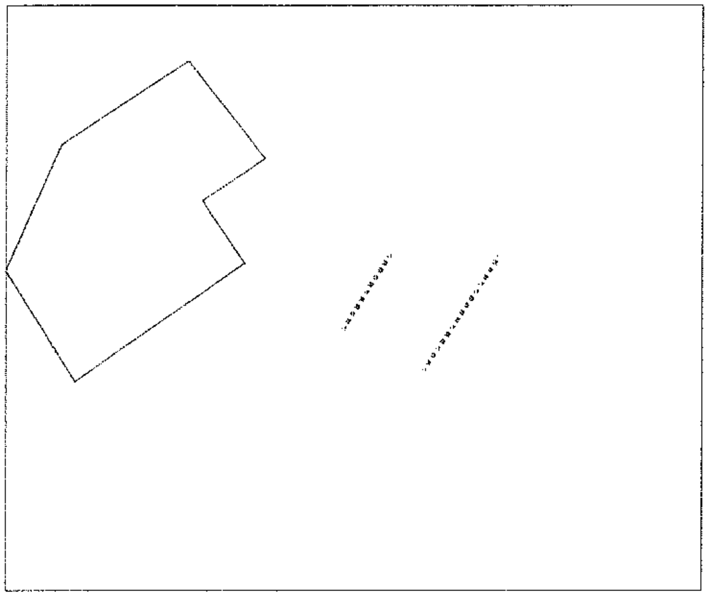
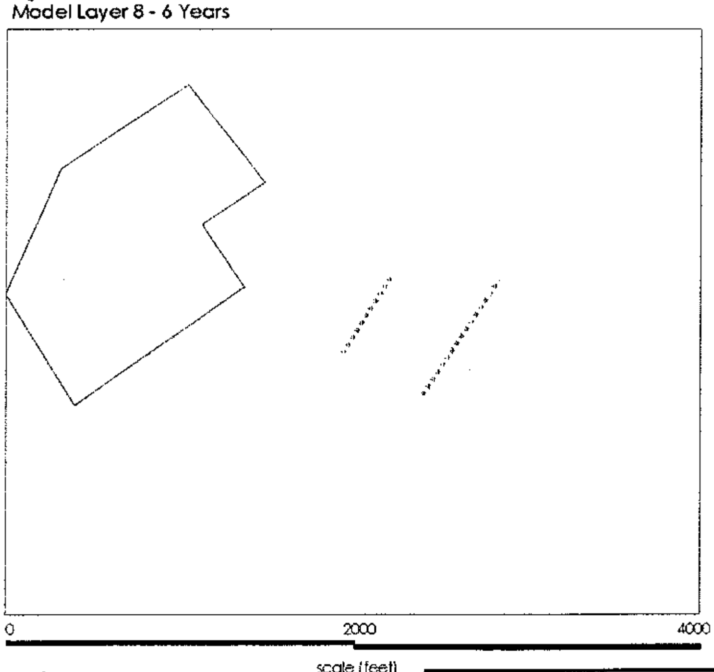


Figure R-E2-51B - Simulated Concentrations for Alternative 11 - Model Layer 8 - 6 Years



Legend

—10.0— Contours of simulated TCE concentrations, in micrograms per liter (µg/L)

Biobarrier Location

Revised Groundwater Feasibility Study for IR Site 70

Figure R-E2-51A, B

IR Site 70 - Simulated Concentrations for Alternative 11 - Model Layer 8 - 6 and 15 Years

Naval Weapons Station, Seal Beach, California

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File No: 127R4593
Job No: HY0888
Rev No: A

Feasibility Study_E2-41A-2.ai

Figure R-E2-52A - Simulated Concentrations for Alternative 11 - Model Layer 9 - 6 Years

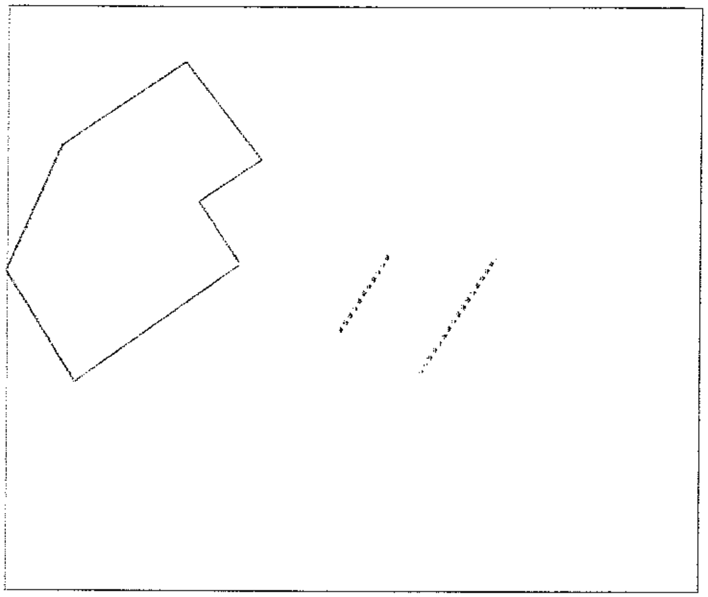
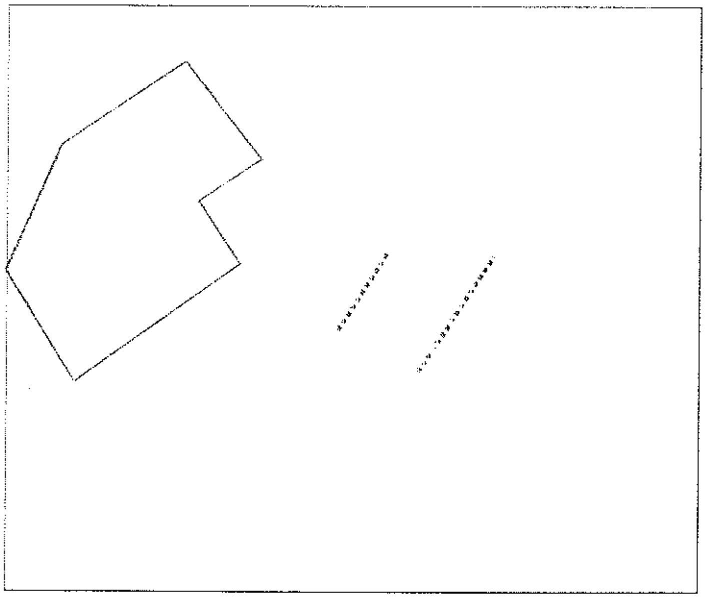


Figure R-E2-52B - Simulated Concentrations for Alternative 10 - Model Layer 9 - 15 Years



0 2000 4000

scale (feet)

Legend

—10.0— Contours of simulated TCE concentrations, in micrograms per liter (μg/L)

·········· Biobarrier Location

Revised Groundwater Feasibility Study for IR Site 70

Figure R-E2-52A, B

IR Site 70 - Simulated Concentrations for Alternative 11 - Model Layer 9 - 6 and 15 Years

Naval Weapons Station, Seal Beach, California

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Job No: HY0888
Rev No: A

Table R-E2-9
1R Site 70 - Transport Model Mass Balance

Alternative	Model Layer	Mass At Start: Total Mass[a] (lb)	Mass At Start: Removed by *In Situ* Treatment[b] (lb)	Mass At Start: Initial Plume Mass (lb)	Mass After 50 Years – Groundwater Plume: Final Plume Mass (lb)	Mass After 50 Years – Groundwater Plume: Plume Mass Pumped (lb)	Mass After 50 Years – Groundwater Plume: Pumping Rate /Well (gpm)	Mass After 50 Years – Dewatered Zone: Remaining Dewatered Mass[d] (lb)	Mass After 50 Years – Dewatered Zone: Decayed Dewatered Mass[d] (lb)
Alternative 6 (hydraulic containment D2 and *in situ* treatment S2)	1	501	416	85	0.03		[e]		
	2	475	394	81	0.01	-			
	3	358	297	61	0.04	-			-
	4	140	7	133	0.13	-		-	-
	5	75	-	75	0.05	-		-	
	6	819	-	819	0.01	1,451	-	-	
	7	621	-	621	0		-	-	
	8	153	-	153	0	-	-	-	-
	9	153	-	153	0	344		-	-
Cell concentration data:		*3,295*	*1,114*	*2,181*	*0.3*	*1,796*			
MT3D cumulative mass budget:						*1,796*	*353*		
Estimate for dewatered zone:								*0.01*	*31*
Alternative 7 (hydraulic containment D2 and pump and treat S3)	1	501	-	501	0[c]	-			
	2	475	-	475	0	532			
	3	358	-	358	0.03	-		-	-
	4	140	-	140	0.14			-	-
	5	75		75	0.04	-	-	-	-
	6	819		819	0	1,450	-	-	
	7	621	-	621	0	-	-	-	-
	8	153	-	153	0		-	-	-
	9	153	-	153	0	339	-		-
Cell concentration data:		*3,295*	*0*	*3,295*	*0.2*	*2,322[f]*			
MT3D cumulative mass budget:						*2,287*	*664*		
Estimate for dewatered zone:								*0.2*	*344*
Alternative 9 (pump and treat D3 and *in situ* treatment S2)	1	501	416	85	0[c]	-			
	2	475	394	81	0	35			
	3	358	297	61	0.02			-	-
	4	140	7	133	0	112		-	-
	5	75	-	75	0	-		-	-
	6	819		819	0	1,600			-
	7	621		621	0	-	-		-
	8	153		153	0		-	-	-
	9	153	-	153	0	331	-		
Cell concentration data:		*3,295*	*1,114*	*2,181*	*0.02*	*2,077[f]*			
MT3D cumulative mass budget:							*229*		
Estimate for dewatered zone:								*0.02*	*49*
Alternative 10 (pump and treat D3 and pump and treat S3)	1	501		501	0[c]				
	2	475		475	0	527			
	3	358	-	358	0.01	-			-
	4	140	-	140	0	-		-	
	5	75	-	75	0	-	-	-	
	6	819	-	819	0	1,701		-	-
	7	621	-	621	0				
	8	153	-	153	0	-	-	-	-
	9	153	-	153	0	334	-	-	-
Cell concentration data:		*3,295*	*0*	*3,295*	*0.01*	*2,562[f]*			
MT3D cumulative mass budget:						*1,902*	*229*		
Estimate for dewatered zone:								*0.02*	*49*

Alternative	Model Layer	Total Mass At Start (lb)[a]	Mass Remaining After 6 Years (lbs)[g]	Mass Remaining After 15 Years (lbs)[g]
Alternative 11 (biostimulation and bioaugmentation using biobarriers of DNAPL source and dissolved plume)	1	501	499.6	618.5
	2	475	7.7	2.7
	3	358	3.7	0.0
	4	140	1.5	0.0
	5	75	0.0	0.0
	6	819	4.4	0.0
	7	621	0.7	0.0
	8	153	0.0	0.0
	9	153	0.0	0.0
Mass Estimated from Volume Weighted Concentrations:[h]		*3,295*	*517.6*	*621.2*
Mass remaining in plume, not including constant source influx:[i]			*18.0*	*2.7*

Notes:

[a] Potential presence of residual DNAPL in source area is not included in mass estimations.

[b] In situ treatment (S2) is assumed to reduce concentrations within source area >10,000 μg/L to 5μg/L for alternatives 6 and 9. Reduction in concentrations of Alternative 11 related to in situ treatment were simulated using Visual MODFLOW/RT3D v2.5 assuming a constant concentration source of 11,000 μg/L for 15 years.

[c] For alternatives 6 through 10, the degradation rate is included for model layers 1 through 4, based on literature value for half-life of 4.5 years (Table E2-8). Degradation rate for other model layers is not included, based on negligible presence of degradation products below 60 feet bgs (Figure E2-7).

[d] Pump and treat near the source area (Alternative 9) and within the source area (Alternatives 7 and 10) result in dewatering of the shallow clay and underestimation of remaining mass. Fate of mass in dewatered zone is based on calculation of decay over 50 years, with half-life of 4.5 years.

[e] Blank indicates value is not determined.

[f] Slight calculation difference occurs between cell concentration data and MT3D cumulative mass budget for "plume mass pumped." MT3D mass balance is considered a more accurate estimate. The estimate from cell concentration history is based on less accurate linear interpolation between time steps. Mass removal history shown in Figure E2-42 is based on the well concentration history, because MT3D does not provide time-history for individual wells, only for entire model.

[g] For alternative 11, the degradation rate is included for all model layers, based on literature values for half-lives of natural attenuation and biostimulation (Table E2-8). The natural attenuation degradation rate for model layers 5 to 10 is assumed to be greater than zero, due to the presence of biodegradation byproducts at depth.

[h] Mass remaining estimates including layer 1 are artificially inflated due to: (*i*) a constant concentration condition assigned to the model to simulate the presence of DNAPL, and (*ii*) the assumption of no enhanced degradation rate in this zone. Little information is available regarding the distribution and mass of DNAPL present within this layer. Initial estimates of DNAPL mass are not available; therefore, the initial and remaining mass of TCE in the source area cannot be determined.

[i] Total plume mass estimates are shown for model layers 2 through 10, which do not include the impact of the constant concentration source and better illustrate the effectiveness of the biobarriers in treating the plume mass.

Acronyms/Abbreviations:
bgs – below ground surface
DNAPL – dense nonaqueous-phase liquid
lb – pounds
μg/L – micrograms per liter

R-E2.3.5 Relative Effectiveness of Alternatives

This section describes the relative effectiveness of Alternatives 6, 7, 9, 10, and 11 in terms of total mass removed and time to achieve cleanup. The model simulation results are shown as an initial and final mass balance summary in Table R-E2-9, as simulated cumulative mass removed versus time in Figures E2-42 (in the original FS [BNI, 2002]) and R-E2-42, and as time required to achieve a concentration of 5 μg/L for each model layer in Table R-E2-10. Table R-E2-10 also summarizes the number of wells, pumping rates and biobarriers as relevant for each model layer.

The time required to achieve cleanup is based on an assumed cleanup goal of 5 μg/L. For the model simulations conducted by BNI (2002), *in situ* treatment is assumed to immediately achieve this cleanup goal within the source area (i.e., Alternatives 6 through 10). For Alternative 11, effectiveness of the source treatment in containing and treating mass discharge from the DNAPL is evaluated by simulating the degradation rates of TCE and its breakdown components (e.g., cDCE, VC, ethene). DNAPL mass removal effectiveness could not be evaluated. The ranking of alternatives in terms of time required to achieve cleanup, from fastest to slowest, is as follows:

- Alternative 11, bioremediation using biobarriers (DA/DB), achieves a reduction of TCE to 5 μg/L in the plume in less than 15 years. The majority of the plume mass is removed within 4 to 6 years, after which MNA processes result in complete degradation of the plume within the following 2 years. Bioremediation (SA/SB) within the source area is shown to successfully contain and treat the mass discharge of TCE from the DNAPL and the resulting daughter products. There are pockets of low concentrations of VC remaining immediately surrounding the source zone, but these are expected to mitigate once sufficient DNAPL mass has been degraded.

- Alternative 9, pump and treat (D3) and *in situ* treatment (S2), achieves a reduction to 5 μg/L in all layers after 46 years. Layers below the interbedded unit are reduced to 5 μg/L in 11 to 18 years. Extending the area of *in situ* treatment within the fine-grained soils of the interbedded unit would reduce the cleanup time for the fine-grained portion. (Simulating dewatering of the shallow clay appears to cause a significant underestimation of cleanup time for this clay, and underestimation is most significant for Alternatives 7 and 10, but negligible for Alternative 6.)

- Alternative 6, hydraulic containment (D2) and *in situ* treatment (S2), achieves a reduction to 5 μg/L in all layers after 25 to 47 years. (The cleanup time for the shallow clay is negligibly affected by dewatering for this alternative.)

- Alternative 10, pump and treat (D3) and pump and treat (S3), fails to achieve a reduction within 50 years to 5 μg/L in the fine-grained material of the interbedded unit, although other layers below the shallow clay are reduced to 5 μg/L within 11 to 34 years. (Aggressive pumping is found to be counterproductive to cleanup of the shallow clay and upper portion of the interbedded unit because of dewatering effects.)

- Alternative 7, hydraulic containment (D2) and pump and treat (S3), fails to achieve a reduction to 5 μg/L within 50 years in the fine-grained material of the interbedded unit, although other layers below the shallow clay are reduced to 5 μg/L within 25 to 44 years.

Cleanup times could be underestimated for the first and second sand units, depending upon the extent of localized silt and clay lenses and resulting increased adsorption and decreased migration rate. In addition, cleanup times by pump and treat of the source area in the shallow clay and interbedded unit could be significantly underestimated if potential residual DNAPL is present. Moreover, as noted above, dewatering of the clay in Alternatives 7, 9, and 10 likely causes an underestimate of the cleanup time for that layer.

The initial mass of dissolved and adsorbed TCE for the IR Site 70 plume is estimated as 3,300 pounds. For the total mass removed, the ranking of the alternatives, from most to least effective, is as follows:

- Alternative 11, bioremediation of plume and source, removes approximately 3,280 pounds within the first 6 years Approximately 15 pounds of TCE is estimated to undergo natural attenuation within the plume over the following 9 years The mass of TCE removed within the source area cannot be determined at this time.

- Alternative 9, pump and treat (D3) and *in situ* treatment (S2), removes approximately 1,100 pounds by *in situ* treatment and approximately 1,900 pounds by pumping after 10 years. Approximately 300 pounds of TCE is estimated to undergo natural attenuation degradation over 50 years.

- Alternative 6, hydraulic containment (D2) and *in situ* treatment (S2), removes approximately 1,100 pounds by *in situ* treatment and approximately 1,800 pounds by pumping after 30 years. Approximately 400 pounds of TCE is estimated to undergo natural attenuation degradation over 50 years.

Table R-E2-10
1R Site 70 - Simulated Time Required to Achieve TCE Concentration of 5 ug/L

Alternative	Model Layer	Hydrostratigraphic Unit	Dissolved Plume: Number of Wells	Dissolved Plume: Pumping Rate/ Well (gpm)	Source Area: Number of Wells	Source Area: Pumping Rate/ Well (gpm)	Total Pumping (gpm)	Initial Maximum Concentration[a] (µg/L)	Simulated Time To Reach 5 µg/L[b] (years)	At 50 Years Simulated Maximum Concentration (µg/L)
Alternative 6 (hydraulic containment D2 and *in situ* treatment S2)	1	Shallow clay	-	-	-	-		8,785	46	3
	2	Interbedded - upper	5	1	-	-	5	8,785	37	0
	3	Interbedded - lower	-	-	-	-		8,785	47	3
	4	First sand - upper		-	-	-		9,924	40	0
	5	First sand - middle	-	-		-		9,924	44	0
	6	First sand - lower	2	80			160	7,868	41	0
	7	Shell horizon	-	-	-	-		7,868	36	0
	8	Second sand - upper	-	-	-	-		1,254	30	0
	9	Second sand - lower	1	80	-	-	80	1,254	25	0
	Total		*8*				*245*			
Alternative 7 (hydraulic containment D2 and pump and treat S3)	1	Shallow clay[c]	-	-	-	-		295,239	8[c]	0[c]
	2	Interbedded - upper	5	1	9	1	14	295,239	34	0
	3	Interbedded - lower	-	-	-	-		295,239	>50	12
	4	First sand - upper	-	-	-	-		12,468	41	0.7
	5	First sand - middle	-	-	-	-		12,468	44	0.4
	6	First sand - lower	2	80	-	-	160	7,868	41	0
	7	Shell horizon	-	-	-	-		7,868	38	0
	8	Second sand - upper		-	-	-		1,254	30	0
	9	Second sand - lower	1	80	-	-	80	1,254	25	0
	Total		*8*		*9*		*254*			
Alternative 9 (pump and treat D3 and *in situ* treatment S2)	1	Shallow clay[c]	-	-	-	-		8,785	9[c]	0[c]
	2	Interbedded - upper[d]	5	1	3	1	8	8,785	26	2.4
	3	Interbedded - lower	-	-	-	-		8,785	46	0
	4	First sand - upper	2	9	-	-	18	9,924	18	0
	5	First sand - middle	-	-	-	-		9,924	15	0
	6	First sand - lower[e]	4	80	-	-	320	7,868	17	0
	7	Shell horizon	-	-	-	-		7,868	16	0
	8	Second sand - upper	-	-	-	-		1,254	14	0
	9	Second sand - lower	2	50			100	1,254	11	0
	Total		*13*		*3*		*446*			
Alternative 10 (pump and treat D3 and pump and treat S3)	1	Shallow clay[c]	-	-	-	-		295,239	7[c]	0[c]
	2	Interbedded - upper	5	1	9	1	14	295,239	34	0
	3	Interbedded - lower	-	-	-	-		295,239	>50	6
	4	First sand - upper		-	-	-		12,468	25	0
	5	First sand - middle	-	-	-	-		12,468	19	0
	6	First sand - lower[e]	4	80	-	-	320	7,868	16	0
	7	Shell horizon	-	-	-	-		7,868	12	0
	8	Second sand - upper	-	-	-	-		1,254	13	0
	9	Second sand - lower	2	50	-	-	100	1,254	11	0
	Total		*11*		*9*		*434*			

Alternative	Model Layer	Hydrostratigraphic Unit	Dissolved Plume: Number of Biobarriers (No. of Wells)	Dissolved Plume: Biobarrier Spacing (ft)	Source Area: Number of Wells	Source Area: Number of Biobarriers (No. of Wells)	Initial Maximum Concentration (µg/L)	Simulated Time To Reach 5 µg/L[f] (years)	At 15 Years Simulated Maximum Concentration (µg/L)
Alternative 11 (biostimulation and bioaugmentation using biobarriers of DNAPL source and dissolved plume)	1	Shallow clay	-	-	-	-	295,239	27	12000[f]
	2	Interbedded - upper	-	-	48	1 (8)	295,239	20	140
	3	Interbedded - lower	-	-	48	1 (8)	295,239	7	0.7
	4	First sand - upper	-	-	48	1 (8)	12,468	6	0
	5	First sand - middle	4 (104)	500	-	-	12,468	5	0
	6	First sand - lower	4 (104)	500	-	-	7,868	7	0
	7	Shell horizon	-	-	-	-	7,868	6	0
	8	Second sand - upper	2 (52)	500	-	-	1,254	5	0
	9	Second sand - lower	2 (52)	500	-	-	1,254	5	2
	Total		*6 (156)*		*48*	*1 (8)*			

Notes:
[a] *In situ* treatment (S2) is assumed to reduce concentrations within source area from >10,000 to 5 µg/L.
[b] Potential presence of residual DNAPL in source area is not included in simulations; impact of residual DNAPL would be to significantly prolong the pumping period for hydraulic containment of source area (S3) for model layers 1 through 3.
[c] Pump and treat near the source area and within the source area result in dewatering of shallow clay and underestimation of cleanup time and remaining concentrations.
[d] Number of wells under "Source Area" modeled as source area for dissolved plume.
[e] For model layer 6, in Alternatives 9 and 10, two wells are pumped at 70 gpm and two other wells are pumped at 90 gpm.
[f] Potential presence of residual DNAPL in source area for was accounted for in simulations for Alternative 11 by assigning a constant concentration boundary condition within the source area, with an assumed duration of 15 years.

Acronyms/Abbreviations:
DNAPL – dense nonaqueous-phase liquid
gpm – gallons per minute
µg/L – micrograms per liter

- Alternative 10, pump and treat (D3) and pump and treat (S3), removes approximately 2,400 pounds by pumping after 10 years. Approximately 900 pounds of TCE is estimated to undergo natural attenuation over 50 years.
- Alternative 7, hydraulic containment (D2) and pump and treat (S3), removes approximately 2,300 pounds by pumping after 30 years. Approximately 1,000 pounds of TCE is estimated to undergo natural attenuation degradation over 50 years.

If residual DNAPL is present, initial mass and mass removed will have been significantly underestimated in the simulations. The simulated mass removed by pumping for Alternative 7 and 10, without *in situ* treatment, would be most affected, with much higher mass removed and much longer pumping time. Regardless of numerical modeling results that might have included residual DNAPL, it is appropriate to question whether pumping alone could practically remediate to a concentration of 5 μg/L, particularly with fine-grained soil present.

R-E2.4 MODEL UNCERTAINTY

This section summarizes model sensitivity analyses for selected parameters and provides recommendations to reduce model uncertainty.

Significant areas of uncertainty in the modeling simulations include the following:

- Mass and distribution of residual DNAPL present;
- Biodegradation rate (enhanced and natural) in the plume, including the high-concentration source area and shallow clay;
- Hydraulic conductivity, or transmissivity, in hydrostratigraphic units without pumping tests, i.e., below the upper portion of the first sand unit; and
- Hydraulic influence of agricultural wells within NAVWPNSTA Seal Beach and possible influence from other more distant water supply and injection wells.

R-E2.4.1 Sensitivity Analysis

Additional model simulations for Alternative 11 (*in situ* bioremediation of dissolved plume and source area) were evaluated for changes to uncertain parameter values that might significantly affect the modeling results. The following sensitivity analyses were evaluated:

- Biodegradation rate constant Changed natural attenuation biodegradation rate constant for model layers 4 through 10 from 283 days to 0 (no degradation occurring).
- Biobarrier spacing. Changed biobarrier configuration from 6 biobarriers located at 500 ft spacing, to 2 biobarriers placed at the plume toe only The sensitivity of the remediation duration to the natural attenuation degradation half-life for model layers 4 through 10 was evaluated for this biobarrier configuration by determining the required treatment duration for natural attenuation half-lives of 283 days and 566 days

The results of the sensitivity simulation with the biodegradation rate constant decrease are summarized in Table R-E2-11. The assumed decrease in biodegradation rate constant reduces the remedial effectiveness of the biobarriers. The time required to achieve a maximum concentration of 5 µg/L in the plume increases from 6 to 8 years to >50 years, assuming that electron donor addition was terminated after 4 to 6 years in the plume (4 years at the toe of the plume, 6 years nearer the source where the concentrations are higher). The groundwater within the boundaries of IR Site 70 reduces to below 5 µg/L within this time frame, but the plume migrates off-site. If a lack of natural attenuation was found to occur within the deeper zones, then oil application within the plume biobarriers would need to extend to 10 years, from the current 4 to 6 year design, to achieve 5 µg/L within the plume in less than 50 years.

The change in biobarrier spacing from every 500 ft to plume toe treatment only resulted in the biobarrier operation being extended to 8 years. This duration of treatment is highly sensitive to the rate of natural attenuation within the plume, as indicated by the second set of runs where the natural attenuation half-life was doubled, and the resulting treatment duration was increased to 20 years.

R-E2.4.2 Recommendations to Reduce Uncertainty

Activities for remedial design and remedial action may include additional numerical modeling analyses to refine the biobarrier layout and operational period. From the lessons learned in the preparation of the conceptual model, numerical model, and simulations, the following recommendations are included for subsequent development of the remedial design, or if further analysis is performed for feasibility or pilot studies. These recommendations would reduce uncertainties for subsequent modeling simulations:

- Microcosm study. Perform microcosm studies of natural attenuation and enhanced bioremediation in both the source and plume to determine compound specific degradation rates under enhanced bioremediation and natural conditions.
- Tracer testing. Perform tracer testing in both the source and plume (first and second sand units) using conservative tracers to evaluate the groundwater velocity and direction under ambient flow conditions.
- Residual DNAPL. Define the extent and saturation level of potential residual DNAPL or further define the extent of the high dissolved concentration area (greater than 10,000 µg/L) to accurately delineate the source area for *in situ* treatment. Analyze soil samples for residual DNAPL and total VOCs from the saturated shallow clay and interbedded unit. Include well sump sampling to provide substantiation of absence of free DNAPL.
- Supply wells. Investigate municipal and agricultural wells and evaluate effects on Site 70 groundwater levels, hydraulic gradients, and resulting plume migration direction and rate. Collect information on well construction, geologic logs, and historic monthly well usage rates. This information would also be required as a basis on which to develop appropriate institutional controls.

Table R-E2-11
IR Site 70 - Sensitivity Analysis for Alternative 11

Model Layer	Simulated Time to Achieve TCE Concentration of 5 µg/L (years)		Simulated Maximum Concentration at Simulation End (µg/L)[c]	
	Alternative 11 Base Case (Table R-E2-10)	No Natural Degradation in Deep Layers[a]	Alternative 11 Base Case (Table R-E2-10)	No Natural Degradation in Deep Layers[a]
1	27	27	12,000	0
2	20	20	140	0
3	7	8	0.7	0
4	6	8	0	0.7
5	5	>50[b]	0	120
6	7	>50[b]	0	300
7	6	>50[b]	0	160
8	5	>50[b]	0	70
9	5	>50[b]	2	50

Notes:
[a] Decreased degradation rate, based on assumption of increased half-life (from 283 days to no degradation between the biobarriers).
[b] TCE concentrations within IR Site 70 are below 5 µg/L; however, the plume has migrated off-site.
[c] Simulation end time is 15 years for the base case scenario, and 50 years for the scenario without natural attenuation in the deeper layers.

Acronyms/Abbreviations:
DNAPL – dense nonaqueous-phase liquid
TCE – trichloroethene
µg/L – micrograms per liter
> – greater than

- Biobarrier placement optimization. Perform optimization of biobarrier locations (i.e., determine most effective well locations) to minimize cleanup time and costs.
- Long-term monitoring. Perform long-term monitoring to confirm hydraulic gradients, monitor for changes to hydraulic gradients caused by water supply well pumping, and confirm plume degradation products.
- Plume extent. Although the plume extent is relatively well-defined, perform additional HydroPunch® sampling to confirm plume extent in areas indicated to have highest uncertainty according to kriging analysis.

R-E2.5 REFERENCES

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RESPONSE TO COMMENTS
DRAFT REVISED GROUNDWATER FEASIBILITY STUDY REPORT
INSTALLATION RESTORATION SITE 70
NAVAL WEAPONS STATION SEAL BEACH, SEAL BEACH, CALIFORNIA

Comment by: Patricia Hannon (RWQCB, Santa Ana Region)
Dated: 20 June 2005
Response by: Julie Konzuk, GeoSyntec Consultants Inc.
Dated: 18 July 2005

GENERAL COMMENTS

Comment 1: **Page R-B-27 Section B2.2.2.7 General Groundwater Cleanup Permit** A new general groundwater cleanup permit, Order No. R8-2002-0007, NPDES No. CAG918001, was adopted by the Regional Board on January 23, 2002. In addition, the Board adopted two amendments to this permit: Order No. R8-2002-0033, General Waste Discharge Requirements for the Reinjection/Percolation of Extracted and Treated Groundwater Resulting from the Cleanup of Groundwater Polluted by Petroleum Hydrocarbons, Solvents and/or Petroleum Hydrocarbons Mixed with Lead and/or Solvents; and Order No. R8-2003-0085, which corrects the maximum daily effluent concentration limits that were specified in Order No. R8-2002-0007.	**Response 1:** GeoSyntec will revise Section B2.2.2.7 in Appendix R-B of the Revised Draft RFS to the following: "RWQCB Santa Ana Region issued the General Groundwater Cleanup Permit (General Permit; Order No. R8-2002-0007, National Pollutant Discharge Elimination System [NPDES] No. CAG918001, 23 January 2002) for the treatment of groundwater prior to discharge. The Board adopted two amendments to this permit: Order No. R8-2002-0033 (General Waste Discharge requirements for the reinjection/percolation of extracted and treated groundwater resulting from the cleanup of groundwater); and Order No. R8-2003-0085 (correction to the maximum daily effluent concentration limits specified in Order No. R8-2002-0007). In previous communications, Department of the Navy correspondence 5090 Ser N45S/0224 5 June 2002 to Mr. Gerard J. Thibeault, Executive Officer of the CRWQCB – Santa Ana Region, the Navy contended that a General Ground Water Cleanup Permit (Monitoring and Reporting Program No. R8-2002-0007-002) was not applicable to the Installation Restoration Program (IRP) at Site 70. However, the Navy accepted the substantive requirements in the permit, such as discharge standards, as the ARARs. Section R-2.3, page R-2-3, second set of bullets, fourth bullet. The following will be added to the end of the statement; "and subsequent amendments to the WQCP including R8-2004-0001." Section R-B2.2.2.1, Page R-B-22, Item- *Porter-Cologne Water Quality Control Act* GeoSyntec will add the following to the end of the first paragraph: "New WQO's defined within amendments to the WQCP (R8-2004-0001) will be established for NAVWPNSTA Seal Beach Site 70."

RESPONSE COMMENTS
DRAFT REVISED GROUNDWATER FEASIBILITY STUDY REPORT
INSTALLATION RESTORATION SITE 70
NAVAL WEAPONS STATION SEAL BEACH, SEAL BEACH, CALIFORNIA

Comment by: Patricia Hannon (RWQCB, Santa Ana Region)
Dated: 20 June 2005
Response by: Julie Konzuk, GeoSyntec Consultants Inc.
Dated: 07 July 2005

GENERAL COMMENTS

Comment 1: **Page R-B-27 Section B2.2.2.7 General Groundwater Cleanup Permit** A new general groundwater cleanup permit, Order No. R8-2002-0007, NPDES No. CAG918001, was adopted by the Regional Board on January 23, 2002. In addition, the Board adopted two amendments to this permit: Order No. R8-2002-0033, General Waste Discharge Requirements for the Reinjection/Percolation of Extracted and Treated Groundwater Resulting from the Cleanup of Groundwater Polluted by Petroleum Hydrocarbons, Solvents and/or Petroleum Hydrocarbons Mixed with Lead and/or Solvents; and Order No. R8-2003-0085, which corrects the maximum daily effluent concentration limits that were specified in Order No. R8-2002-0007.	**Response 1: (Continued)** Section R-B2.2.2.1, Page R-B-22, Item- *Comprehensive Water Quality Control Plan for Santa Ana River Basin* GeoSyntec will add the following to the first sentence after beneficial use: "newly defined groundwater management zones, ". Text changes will be made to this section to comply with the WQCP management zones, thereby replacing "Santa Ana Pressure Subbasin" with "Orange County Management Zone". GeoSyntec will revise Table R-B-2-2 Potential State Chemical-Specific ARARs by Medium: Table R-B-2-2, page R-B-11 **State Water Resources Control Board and California Regional Water Quality Control Board, Santa Ana Region**; First Citation will be modified to show the following addition: "Water Quality Control Plan for the Santa Ana Basins (Basin Plan) and amendments including R8 -2002-0007, R8-2002-0033, R8-2003-0085, and R8-2004-0001" GeoSyntec will revise Table R-B-3-2 Potential State Location-Specific ARARs: Table R-B-3-2, page R-B-37, **State Water Resources Control Board and California Regional Water Quality Control Board, Santa Ana Region**; First Citation will be modified to show the following addition: "Water Quality Control Plan for the Santa Ana Basins (Basin Plan) and amendments including R8 -2002-0007, R8-2002-0033, R8-2003-0085, and R8-2004-0001" GeoSyntec will revise Table R-B-4-4 Potential State Action-Specific ARARs, IR Site 70: Table R-B-4-4, page R-B-49 **State Water Resources Control Board and California Regional Water Quality Control Board, Santa Ana Region**; First Citation will be modified to show the following addition: "Water Quality Control Plan for the Santa Ana Basins (Basin Plan) and amendments including R8 -2002-0007, R8-2002-0033, R8-2003-0085, and R8-2004-0001"

Table 2-2
Constituents of Concern – IR Site 70

Constituent of Concern	Screening Level Tap Water Carcinogenic Risk	Percent of Total Tap Water Carcinogenic Risk (All Constituents)	Number of Samples Analyzed	Number of Detections	Frequency of Detection (percent)
1,1-dichloroethene	7E-03	5.59	204	27	13.2
Trichloroethene	1E-02	84.7	204	96	47.1
Vinyl chloride	7E-03	5.9	204	18	8.8
Chloroform	3E-03	2.3	204	21	10.3
Total	—	98.5	—	—	—

Acronym/Abbreviation:
IR – Installation Restoration (Program)

Table 2-4
Estimated IR Site 70 TCE Mass

Groundwater Model Layer	Depth Interval (feet bgs)	Stratigraphic Unit	TCE Mass* (pounds)
1	2.5 – 19.5	Shallow clay	501
2	19.5 – 34.5	Interbedded unit – upper	475
3	34.5 – 39.5	Interbedded unit – lower	358
4	39.5 – 61.5	First sand unit – upper	140
5	61.5 – 81.5	First sand unit – middle	75
6	81.5 – 100	First sand unit – lower	819
7	100 – 113	Shell horizon	621
8	113 – 142.5	Second sand unit – upper	153
9	142.5 – 172	Second sand unit – lower	153
		Total	**3,295**

Note:
* this is the mass of dissolved TCE; an unknown amount of DNAPL may also be present

Acronyms/Abbreviations:
bgs – below ground surface
DNAPL – dense nonaqueous-phase liquid
IR – Installation Restoration (Program)
TCE – trichloroethene

Table 2-6
Remedial Action Objectives – IR Site 70

Constituent of Concern	Exposure Route	Receptor(s)	Remediation Goal* (µg/L)
1,1-dichloroethene	Ingestion	Future residential groundwater users	6
Trichloroethene	Ingestion	Future residential groundwater users	5
Vinyl chloride	Ingestion	Future residential groundwater users	0 5
Chloroform	Ingestion	Future residential groundwater users	100

Note:
* based on ARARs-based maximum contaminant level

Acronyms/Abbreviations:
ARAR – applicable or relevant and appropriate requirement
IR – Installation Restoration (Program)

Table 3-3
Groundwater Alkalinity at IR Sites 40 and 70

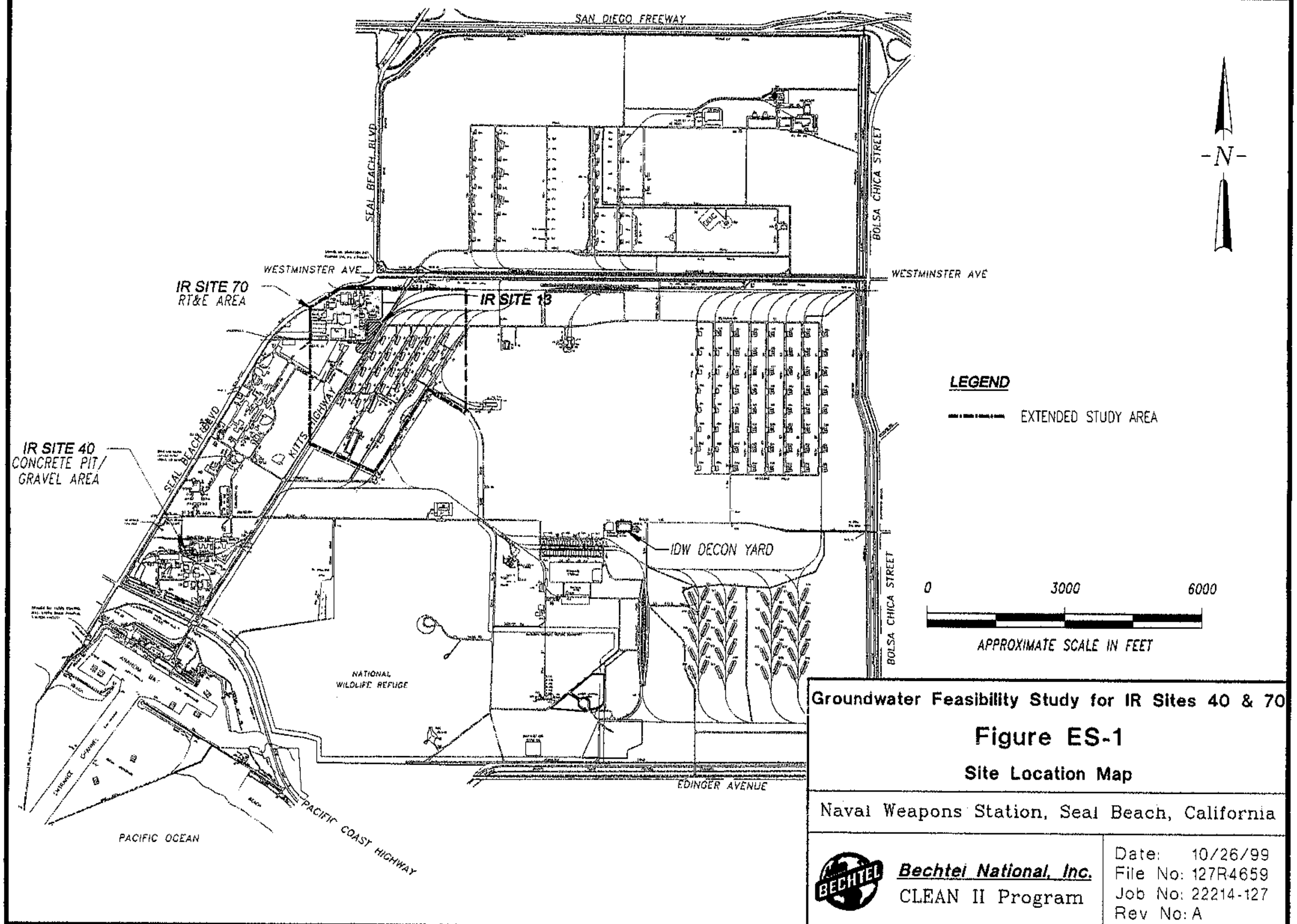
IR Site	Source of Data	Depth Interval (feet)	Range of Alkalinity (as $CaCO_3$, mg/L)
40	Well	≥30	166 – 351
		31 – 40	188
		41 – 65	145 – 191
70	Temporary well point	≥30	155 – 251
		31 – 40	133 – 319
		41 – 50	117 – 168
	Well	≥30	218 – 481
		50 – 60	119 – 235
		95 – 105	131 – 196
		160 – 170	71 – 223
	Drive point	≥30	236 – 627
		31 – 40	140 – 259
		41 – 50	163 – 308
		70 – 80	157 – 228

Acronyms/Abbreviations:
$CaCo_3$ – calcium carbonate
IR – Installation Restoration (Program)
mg/L – milligrams per liter

Table 3-4
Total Dissolved Solids in Groundwater at IR Sites 40 and 70

IR Site	Source of Data	Depth Interval (feet)	Range in TDS (mg/L)
40	Well	≤30	157 – 1,960
		31 – 40	2,540
		41 – 65	3.020 – 11,700
70	Temporary well point	≤30	1,010 – 13,000
		31 – 40	1,430 – 2,710
		41–50	685 – 6,630
		70 – 80	650 – 1,760
	Well	≤30	1,550 – 7,105
		50 – 60	710 – 2,100
		95 – 105	655 – 1,330
		160 – 170	1,040 – 5,620

Acronyms/Abbreviations:
IR – Installation Restoration (Program)
mg/L – milligrams per liter
TDS – total dissolved solids



Groundwater Feasibility Study for IR Sites 40 & 70

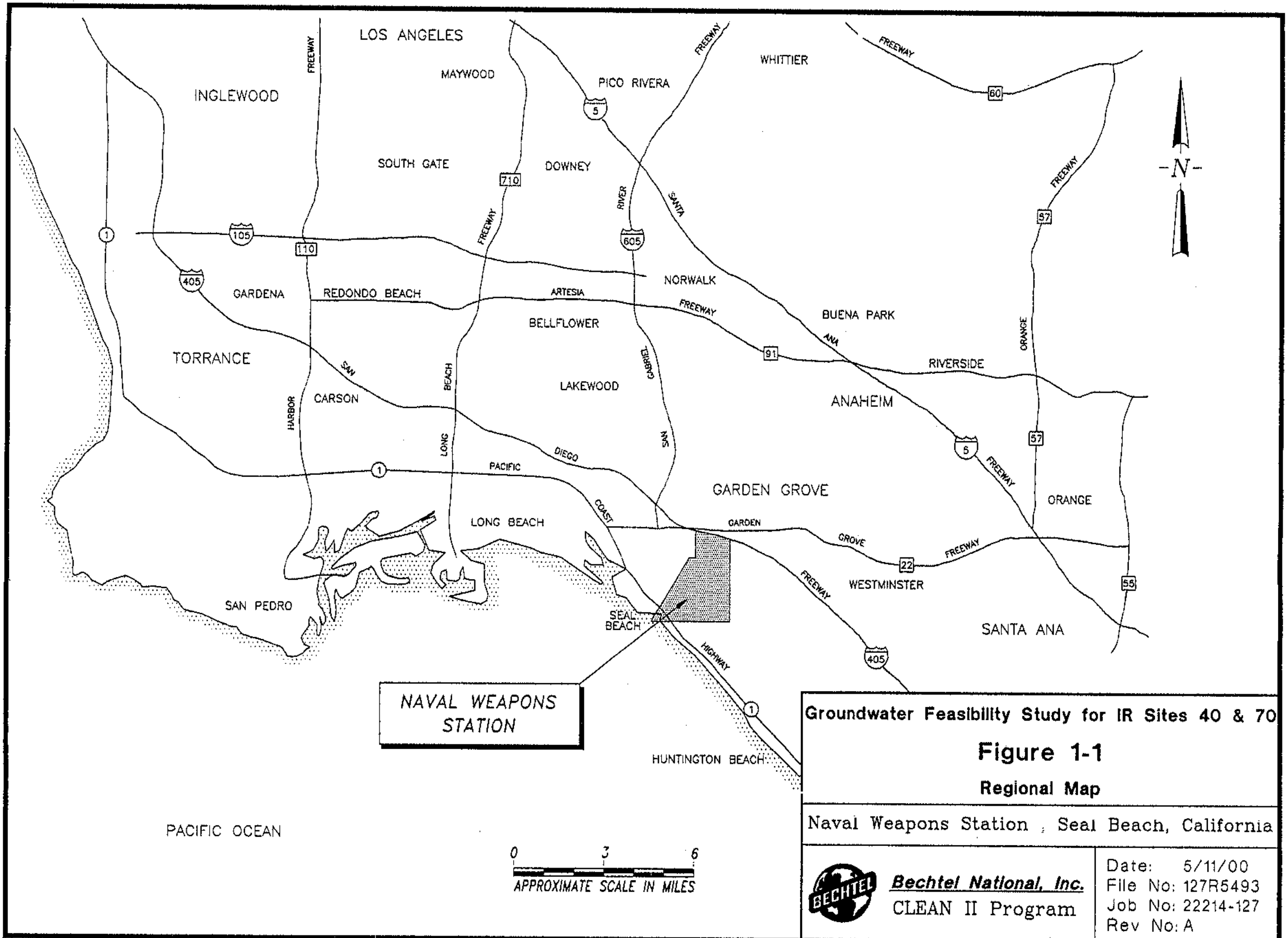
Figure ES-1

Site Location Map

Naval Weapons Station, Seal Beach, California

Bechtel National, Inc.
CLEAN II Program

Date: 10/26/99
File No: 127R4659
Job No: 22214-127
Rev No: A



Groundwater Feasibility Study for IR Sites 40 & 70

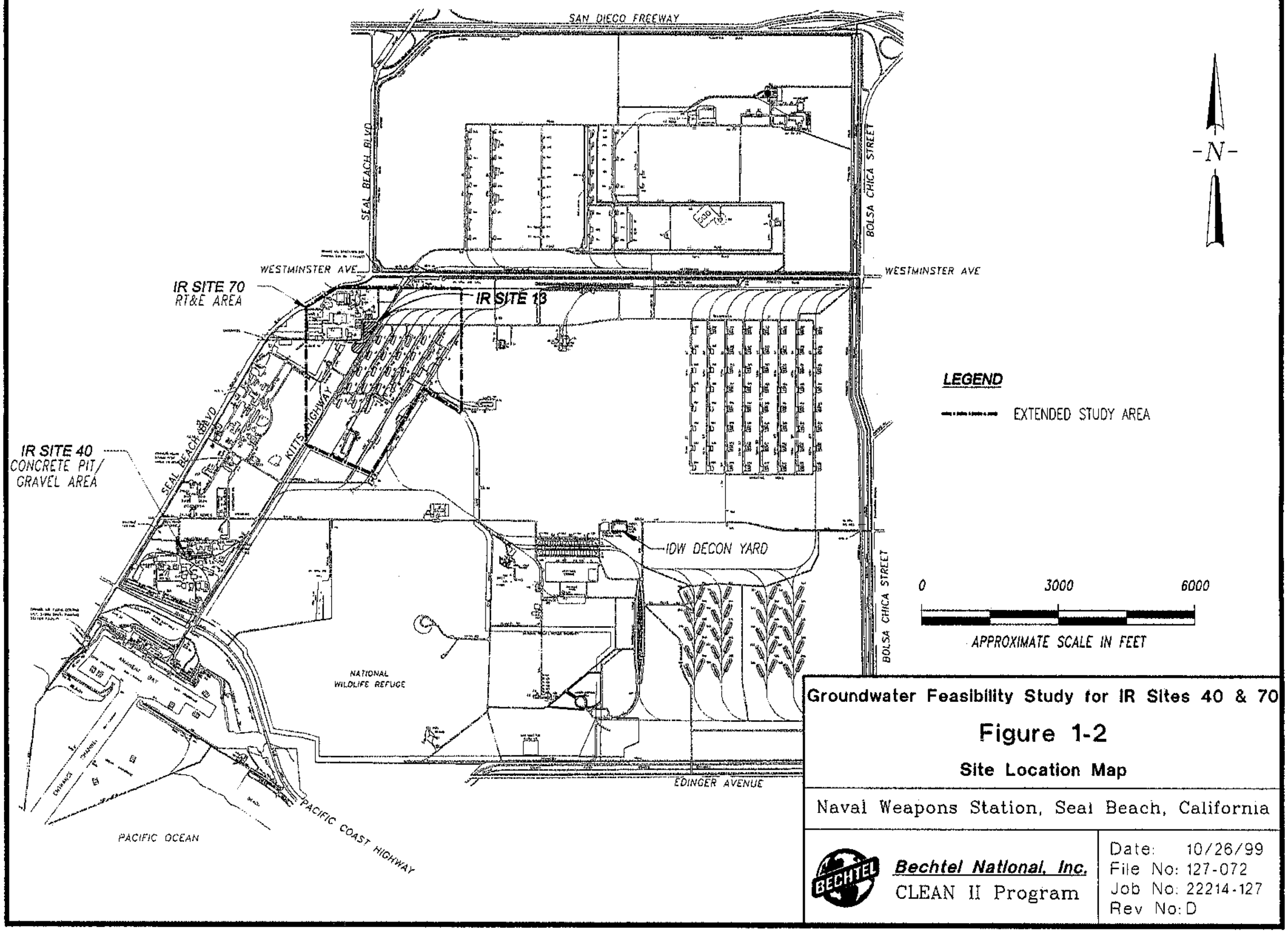
Figure 1-1

Regional Map

Naval Weapons Station , Seal Beach, California

Bechtel National, Inc.
CLEAN II Program

Date: 5/11/00
File No: 127R5493
Job No: 22214-127
Rev No: A



Groundwater Feasibility Study for IR Sites 40 & 70

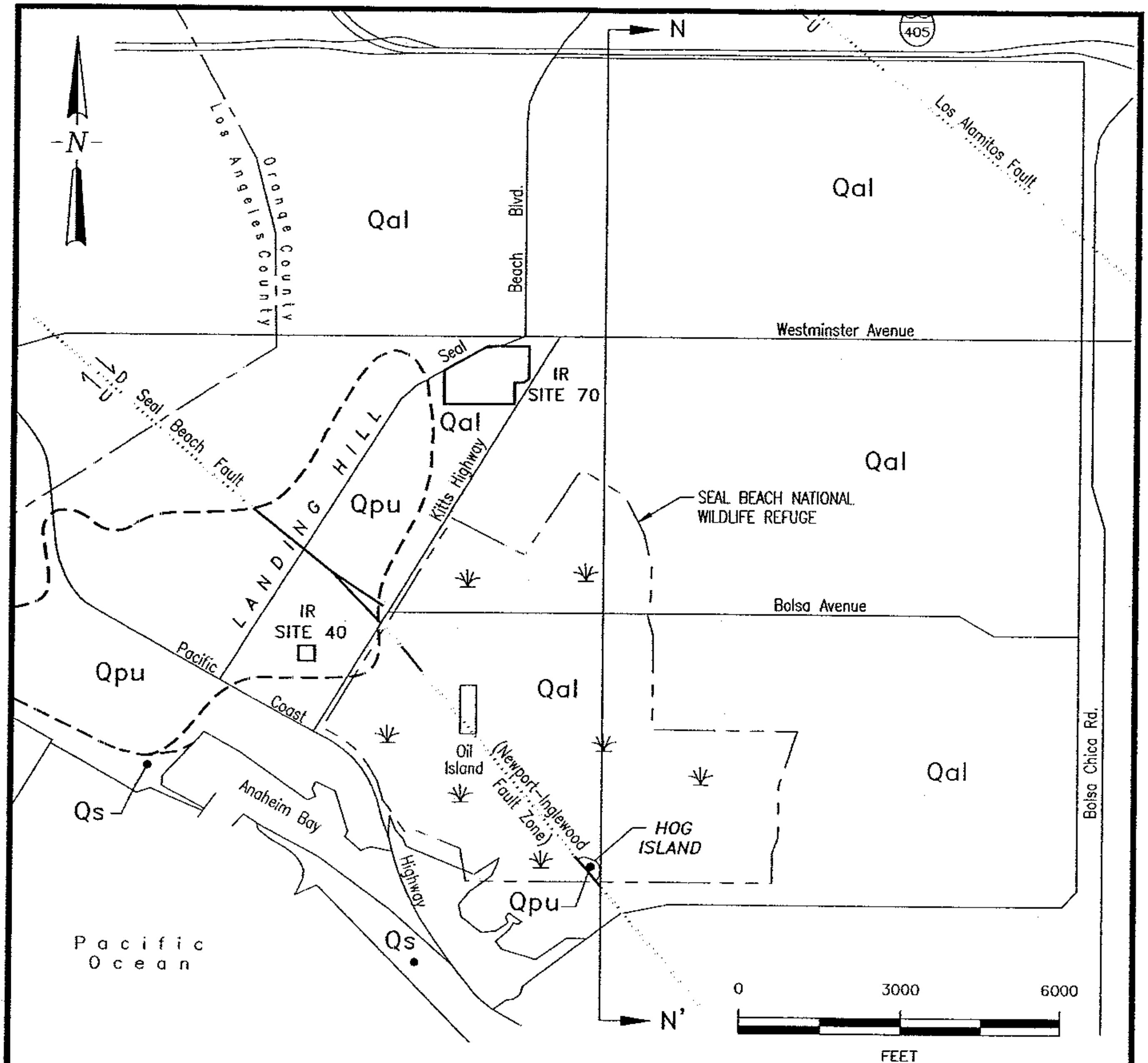
Figure 1-2

Site Location Map

Naval Weapons Station, Seal Beach, California

Bechtel National, Inc.
CLEAN II Program

Date: 10/26/99
File No: 127-072
Job No: 22214-127
Rev No: D



EXPLANATION

Qs	BEACH AND DUNE DEPOSITS, SAND
Qal	ALLUVIUM, UNDIFFERENTIATED, CONTINENTAL AND LAGOONAL SAND, SILT, AND CLAY
Qpu	LAKEWOOD FORMATION CONTINENTAL AND MARINE GRAVEL SAND, SILT AND CLAY
— — — —	APPROXIMATE GEOLOGIC CONTACT
N N'	LOCATION OF CROSS-SECTION ON FIGURE 1-10
U / D	FAULT (DOTTED WHERE CONCEALED) ARROWS INDICATE HORIZONTAL MOTION U/D INDICATE UP/DOWN (VERTICAL) MOTION
⩛	SALT MARSH FROM NEESA (1985)

MODIFIED FROM: FINAL OPERABLE UNIT 4 SITE INSPECTION REPORT (JACOBS 1995).
LOCATION OF SEAL BEACH FAULT FROM SEAL BEACH AND LOS ALAMITOS QUADRANGLE SPECIAL STUDIES ZONES REVISED OFFICIAL MAPS, STATE OF CALIFORNIA (1986).
LOCATION OF LOS ALAMITOS FAULT FROM MONTGOMERY WATSON (1997).
LOCATION OF Qpu-Qal CONTACT FROM POLAND (1956).

Groundwater Feasibility Study for IR Sites 40 & 70

Figure 1-6

General Geology

Naval Weapons Station, Seal Beach, California

Bechtel National, Inc.
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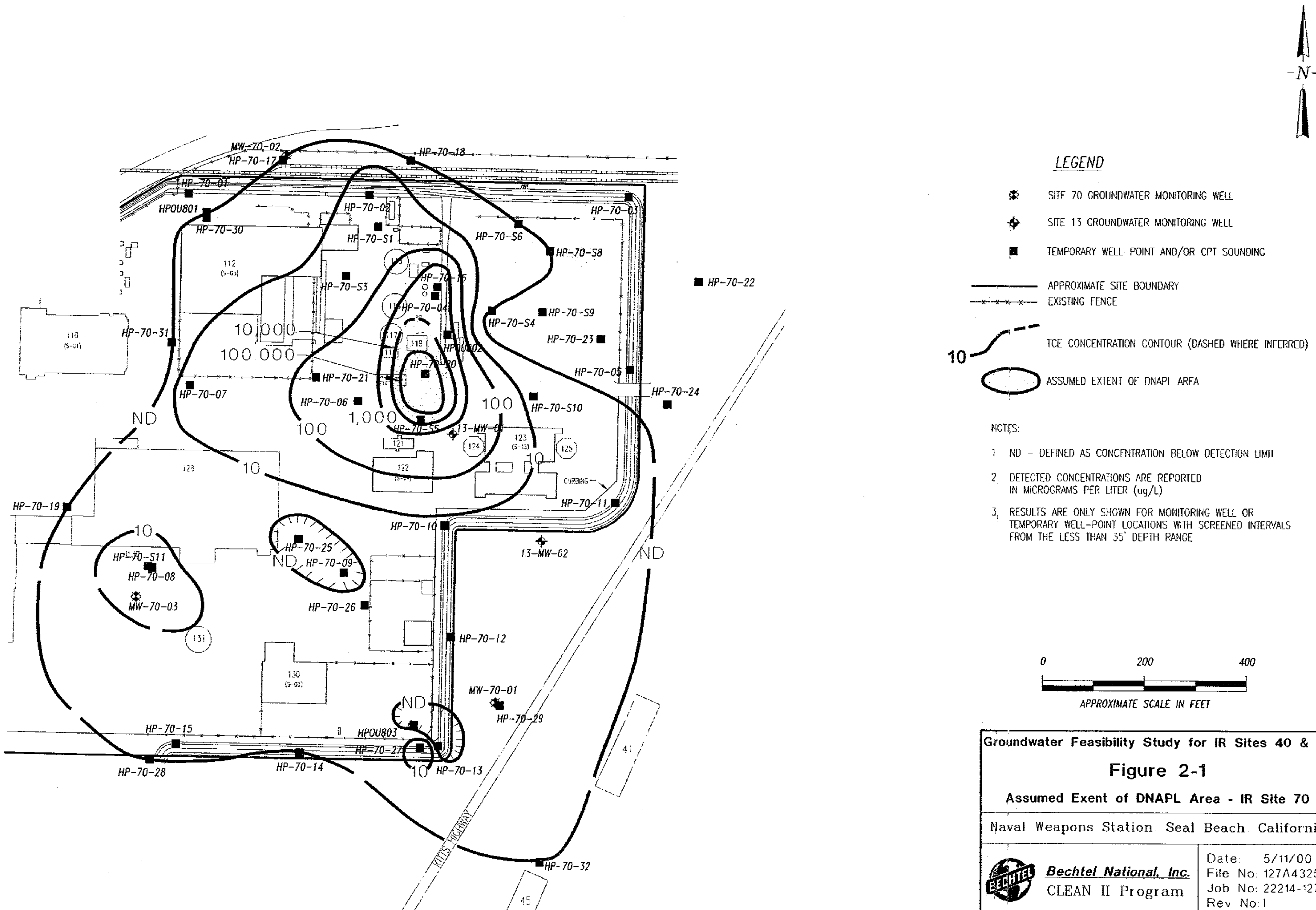
Date: 10/16/99
File No: 127-149
Job No: 22214-127
Rev No: D



Groundwater Feasibility Study for IR Sites 40 & 70

Figure 2-1

Assumed Extent of DNAPL Area - IR Site 70

Naval Weapons Station Seal Beach California

Bechtel National, Inc.
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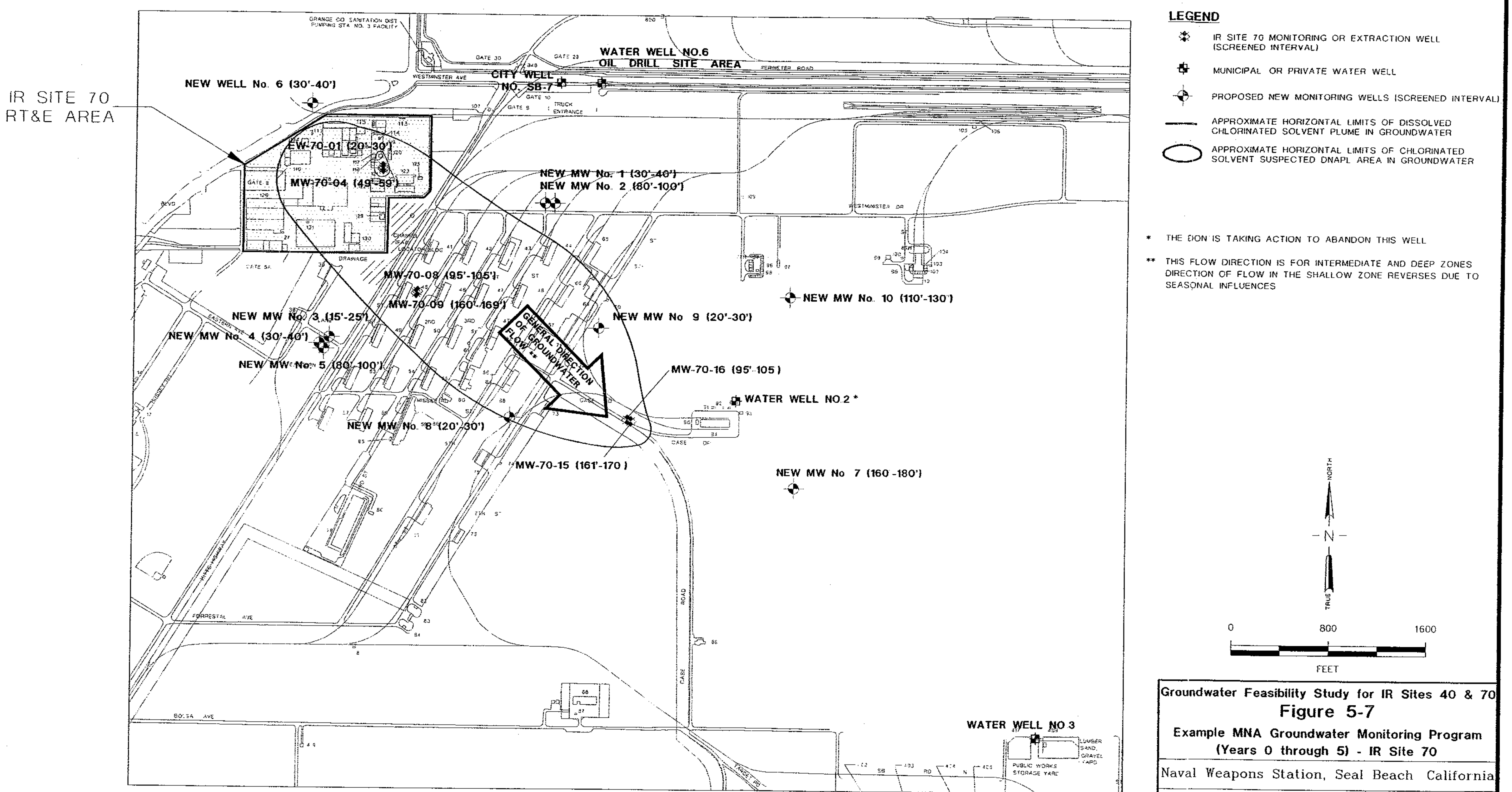
Date: 5/11/00
File No: 127A4325
Job No: 22214-127
Rev No: 1



Groundwater Feasibility Study for IR Sites 40 & 70

Figure 5-7

Example MNA Groundwater Monitoring Program (Years 0 through 5) - IR Site 70

Naval Weapons Station, Seal Beach California

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